METSMaC-I

Strategies for effective learning in the Middle East

Proceedings of the
First Annual Conference for
Middle East Teachers of Science,
Mathematics and Computing

Edited by

Seán M. Stewart
The Petroleum Institute

Janet E. Olearski
The Petroleum Institute

ISBN 9948-8569-0-2

Published by

The Middle East Teachers of Science, Mathematics and Computing (METSMaC)
PO Box 2533
Abu Dhabi
United Arab Emirates

Cite as:
Stewart, S. M. and Olearski, J. E. (Eds) (2005). *Proceedings of the First Annual Conference for Middle East Teachers of Science, Mathematics and Computing*. METSMaC: Abu Dhabi.

Typefaces Times Roman 10 pt and Sans Serif

System The manuscript was typeset using LaTeX on a Linux box by one of the editors (Seán M. Stewart).

Reproduced from a camera ready copy supplied by the editors.

Printed by: ???

Contents

Preface v

Plenary and Keynote Papers **1**

The noble quest: Graduates who think mathematically, *R. Karas* . . . 2

Effective learning strategies for mathematics education, *G. Anthony* . 12

The systematic design of learning, *N. Schley* 24

Oral and Poster Session Papers **31**

Mathematics **33**

Constructing an effective mathematics learning environment for ESL students, *G. Ward* 34

Meeting the challenges of mathematics: Dyscalculia and math anxiety, *C. Lai* 53

Analysis of problem-solving in mathematics teaching and learning, *B. Yushau and D. C. J. Wessels* 60

Algebraic manipulations of polynomials using MS Excel, *M. El-Gebeily and B. Yushau* 67

Coding and decoding messages with Maple, *A. Ayari, M. A. Ayari and S. Ayari* 74

e-Math test bank, *K. Khalil and M. Odeh* 82

Using concrete and semi-concrete modelling: Justification and explanation in teaching mathematics in a classroom-community-based learning environment, *M. H. Rahim* 90

Science **99**

The role of mathematics and physics in engineering degrees, *A. S. Al-Hammadi and R. H. Milne* 100

Burning in a closed environment: Science teachers' conceptions, *H. S. Dhindsa* 107

Some simple physics demonstration experiments, *S. M. Stewart* 121

Secondary science students' perceptions of learning environment and its association with achievement in biology, *B. C-S. Yong* . . . 134
An effective approach to online physics by incorporating home-based experiments, *W. Riego* 147
Combustion: A collection of lecture demonstrations, *P. Rostron* 150
Enhancing teachers' proficiency for better teaching and learning of physics at secondary level, *A. A. Baimba, K. Agyeman and D. P. Brown* 156

Computing **169**
Online learning resource: A Canadian case study that may suit the Middle East, *R. W. Y. Habash, C. Suurtaam, H. T. Alhafid, M. C. E. Yagoub, K. Kara and G. Ibrahim* 170
Multimedia-based effective learning strategies: A case study, *M. V. N. M. R. Kumar and V. S. Mallela* 177
MS Access inquiry lesson: A classroom research project, *R. Al-Sayyed and K. Khalil* 187
Information technology in engineering education, *F. G. Hayati and A. N. Ali* 198
Online webcast: Computer-mediated communications tools used with teachers and students in virtual communities of practice, *V. Stevens* 204
Integrating critical cognitive skills in the IT curriculum of the first year developmental programme of UAE University: Issues, experiences and challenges, *T. Ranginya and P. McKenzie* 219

General **227**
Tips and techniques for designing learning assessments and activities, *N. Schley* 228
Enabling students to cope with information overload: The mind map technique in secondary and higher education, *F. Benyahia* . . 234
Not to extinguish the creative spark in our students, *M. Odeh* 241

Preface

In these proceeding many insights from teachers of the sciences, mathematics, and computing from across the United Arab Emirates, the region, and overseas who are involved in education at the upper secondary, pre-university/foundation, and lower tertiary levels can be found. Contained within these pages you will read of the successes and of the obstacles which continue to challenge and motivate us as content teachers within a context which is both global on the one hand yet unique to the Middle East on the other hand. But above all, you will read of the rewards to both teachers and learners when connections are made and understanding and learning occurs.

The twenty-six articles included in this volume are from a diverse range of teachers found teaching across the sciences, mathematics and computing at either the upper secondary, pre-university/foundation or lower tertiary levels. The contributors themselves are equally diverse with submissions from people teaching in Brunei, Canada, New Zealand, Oman, Qatar, Saudi Arabia, South Africa, the United Arab Emirates, and the United States of America. The volume has been broken up into two sections. Section one contains those papers from the plenary and keynote sessions while section two contains papers from the oral and poster sessions. Considering the three disciplines the conference was attempting to cover within its umbrella, papers in section two have been grouped together under the headings of Mathematics, Science, Computing, and General for ease of identication.

The First Annual Conference for Middle East Teachers of Science, Mathematics and Computing was held at the Armed Forces Officers' Club, Abu Dhabi, from 26–28 April 2005, and hosted by The Petroleum Institute under the patronage of His Excellency Yousef Omair bin Yousef, Secretary General of the Supreme Petroleum Council, Chief Executive Officer of Abu Dhabi National Oil Company, and Chairman of the Governing Board for The Petroleum Institute. The conference attracted some 240 delegates from within the Emirates, across the Gulf, as well as from several overseas countries. The conference featured a plenary speech by Dr Richard Karas and keynote speeches by Dr Glenda Anthony (Mathematics), Dr Musa Shongwe (Science), and Dr Nancy Schley (Computing/General), together with over forty other oral and poster sessions. Inclusion in the proceedings was based on the optional submission of a paper open to all presenters.

Editors
Seán Stewart and Janet Olearski

Plenary and Keynote Papers

The noble quest: Graduates who think mathematically

Richard Karas

Educational Consultant, United States of America

Institutions of higher education in the United Arab Emirates and throughout the Middle East are intent on graduating students fully qualified for professional careers. In this context, the importance of not only mathematical literacy, but the ability to apply mathematical skills to analysis and solve problems is critical. Students must become adept not only in mathematical technique, but also in translating ‘real world’ problems into mathematical representation, and re-translating mathematical solutions into words and actions. Achieving this goal requires a curriculum based on clearly stated, verifiable objectives as well as continuous assessment of students’ skills. While standardised testing can be helpful, it can only be useful if the skills being tested are fully compatible with the aims of the curriculum. Curriculum and curriculum objectives should drive assessment, not the other way round. Several lessons in effective teaching strategies have emerged in recent years, many of them particularly well-suited to Middle Eastern culture. These include:

- Making use of collaborative learning in and out of the classroom.
- Providing rigorous evaluation and feedback – in order for a student to succeed, it must also be possible for him or her to fail.
- Actively engaging students and providing them with rapid feedback.
- Focusing on applications rather than abstractions: focusing on problems that go beyond symbol manipulation.
- Explicitly teaching problem-solving strategies.

Ascertaining the success of these strategies goes beyond testing, it requires partnership and feedback from the ‘customers’ of higher education, the graduates themselves, and the organisations to whom the graduates go after leaving university.

Context

Institutions of higher education in the United Arab Emirates (UAE) and throughout the Middle East are intent on graduating students fully qualified for professional careers. In this context, the importance of mathematical literacy, particularly the ability to apply mathematical skills to analyse and solve problems, is critical: students must become adept not only in mathematical technique but also in translating 'real world' problems into mathematical representation, and re-translating mathematical solutions back into words and actions.

One need look no further than the national newspapers to see vivid evidence of the need for graduates who are adept in critical thinking. Hardly a month goes by without an article on the small, and in some cases, shrinking proportion of private sector jobs occupied by native-born citizens. Attempts to legislate quotas of positions for national citizens may help to alleviate the problem, but the best long-term solution is graduate students who are qualified, better still, over-qualified for the positions they seek. Given the fact that the nation aspires to leadership in banking, commerce, and technology, not to mention food production; all of them based heavily on technology – it is clear that the goal of employable graduates is equally a goal of mathematical reasoning ability. It is also clear that we, the teachers, are at the forefront of an effort that is crucial to the lasting prosperity and civic future of the country, and are the ones entrusted with this noble quest.

Introduction

What does it mean to say that someone can think mathematically? Let us begin by having a bit of fun and in doing so, set the stage for our later discussion. Take a look at the Appendix where you will find a short puzzle. Some who have worked with me at the United Arab Emirates University a few years ago may recognise it, but look again, it is not the one you may know. Take two minutes and see if you can solve it. More importantly, keep track of the facilities and knowledge you are using to solve it.

- Did you begin with your knowledge of binary arithmetic? Why? Did it work?
- Did you consider the inputs and outputs as a truth table?
- If you did use the table in this way, did you look for Boolean operators such as AND, OR, XOR, etc?
- Did the number labels assigned to the switches and bulbs actually have or need cardinal values?
- What was the rule and how did you find it?

Note that solving this problem requires that you:

- translate a physical situation into a symbolic representation;

- attempt to apply a series of one-step techniques;
- attempt a synthesis using several techniques;
- translate the symbolic solution back into words, perhaps even actions.

Perhaps, then, we might define a person who can think mathematically as someone who can competently carry out these functions in order to solve a problem. We might even go a step further and propose them as one standard for graduation.

Objectives, curriculum and assessment

Getting a student trained in basic mathematical skills and educated to think mathematically is not easy, especially when he or she arrives at his or her college, university, or higher education institution with a primary and secondary school education rooted in rote learning.

Steadfastly following a prescribed textbook or teaching toward the problems covered on a standardised test rarely achieves the desired goal. In my own field, physics, it is commonplace to find students who can solve equations and problems, but who have little understanding of the phenomena they are describing and who fail to see a connection between the principles they have learnt and their experiences in the physical world. They know Newton's Laws and they score well on standardised examinations, but they have not connected the principles with the physical world. In addition, they are often unable to apply what they have learnt when they enter the world of work.

Whether it is at the institutional, departmental, or course level, learning objectives should drive curriculum, textbook selection, and testing, rather than the other way round. At the very least, each institution and department that implements standardised assessments should thoroughly understand the knowledge and skills being tested before adopting a given instrument. Be sure that the examination tests what you want your students to know, and in particular, be sure that it includes assessment of mathematical thinking as we have defined it.

Even when they find assessment instruments that match their curriculum, most institutions fail to complete the loop; they do not continuously tune their curriculum according to the results of their assessments. We all know that the attitudes, skills, and knowledge of incoming students change and that employers' expectations of graduates evolve as well. Thus, in addition to simply wanting to improve teaching, continuous assessment of learning outcomes and comparison with objectives keep institutions, departments, and teachers at the forefront of teaching and learning.

A simple data analysis technique can provide day-to-day and semester-to-semester assessment of students' progress as well as the effectiveness of homework, in-class assignments, and course outcomes. Consider the question, 'Are classroom assignments consistent with examination content?' By constructing a scatter plot of students' homework versus examination marks, one can get at least a preliminary answer. By selecting

different quantities to display along the x and y axes of such plots, one can ask about the consistency between examinations, between homework and examinations, and even about consistency of marking and student progress from course to course.

Teaching strategies

Several lessons in effective teaching strategies have emerged in recent years, many of them particularly well-suited to Middle Eastern culture. They include:

- actively engaging students and providing them with rapid feedback;
- providing rigorous evaluation and feedback; in order for a student to succeed, it must also be possible for him or her to fail;
- making use of collaborative learning in and out of the classroom;
- focusing on applications rather than abstractions; focusing on problems that go beyond symbol manipulation;
- explicitly teaching problem-solving strategies.

Recent research shows that requiring students to construct their own knowledge and skills is far more successful than expecting them to receive material from lectures and textbooks. Lecture and tutorial sessions that provide opportunities for asking questions and discussing concepts in small groups, although better than straight lecturing, are far less effective than classroom environments that require students' active engagement.

Why is the traditional classroom lecture/discussion approach not effective? Consider the following:

- Serious students maximum attention span is about 10–15 minutes.
- The information given in a lecture zips by without time for serious contemplation. Add to this the fact that most students are insufficiently versed in spoken English even to keep up with what is being said, and it is hard to imagine there being much retention of material presented in the lecture format.
- Most students' note-taking skills are abysmal.
- Most of the material presented in lecture/discussion is covered equally well, perhaps better, in the textbook.

Active engagement is based on just a few, easily articulated principles.

1. In the classroom, students spend most of their time doing, thinking, and talking, not listening to a teacher talk about the subject.
2. Students interact heavily with other students.

3. Students receive rapid feedback to help keep them on track.

4. The teacher acts as a mentor and facilitator, not as the giver of knowledge.

5. Most importantly, students take responsibility for their knowledge and skills, using all of the resources available to them. The obvious corollary to this principle is that it is the teacher's responsibility to tell his or her students what they are expected to know.

This sort of environment is quite a departure from traditional practices, particularly in terms of the respective roles of the teacher and the student.

Example: Co-operative Groups (After Heller (2005))
In a co-operative groups classroom, the teacher initially assigns students to small groups of three to four, based on placement examination results. Each group includes a student from the top, middle, and lower third of the examination scores. Surprisingly, this does not result in the weaker students 'coasting' on the work of the stronger ones, provided that each student is assigned a role within his or her group.

- Manager: leads the discussion, keeps the group on task.
- Sceptic: tries to 'poke holes' in solutions offered.
- Recorder: writes up the group's work, orally reports the group's results to the rest of the class, and hands in the group's written work for marking.

Roles are rotated every week, and students receive their marks based on two sets of evaluations: (a) their group work (in which all students in a group receive the same mark), and (b) their individual work on examinations. Typically a weighting factor of 30–40% is placed on group work and 40–60% is placed on individual work. This weighting helps reinforce the necessity for weaker students to construct their own knowledge and skills.

There are many ways to attain active engagement. Several strategies have been shown to be effective. 'Co-operative Groups', a strategy developed by Patricia Heller and colleagues at the University of Minnesota is one example of this. It seems particularly well suited to a Middle Eastern setting where collaboration ('helping one another') is a cultural norm. The teacher in such a course does a minimum of lecturing. Instead, he or she spends his or her time constructing problems, ranging from simple to complex, that are rooted in context as much as possible. The problems read like stories and pose questions with multiple facets, for example, 'Where do you start?', 'What techniques might work here?', 'Is this solvable?', 'What does the answer tell you?', 'Can you write a new problem that uses this technique or knowledge?' In addition, the

teacher facilitates discussion between groups as they are called upon to present their results, and critiques students' work in a constructive, confidence-building fashion, as discussions proceed. Good work must be reinforced heavily for this reason: the teacher must read the solutions submitted by his or her students and provide written comments and marks as soon as possible while the concepts and their applications are still fresh in the students' minds.

In this environment, the textbook is a primary reference material that students must use (not unlike a dictionary, thesaurus, or grammar text in a language class) to assist them in solving problems. It is not something that the student is required to read (and usually would not if reading the text were simply a course requirement).

Does this sound difficult to implement here in the Middle East? It is. First, most teachers are not used to a role in which they do not prepare and deliver lectures; it is an enormous hurdle, as I learnt personally. Second, students will resist this approach. They are completely unused to being in charge and held accountable for their own learning, and at least initially, they find it very difficult to get up and present their work to you and their peers. There is every temptation for both the teacher and the students to slip back into traditional roles and rote learning. The first third of the course requires tenaciousness on the part of the teacher. However, once students become used to the environment, they tend to accept it very well.

Problems and problem-solving

Sometimes it is helpful to think of a hierarchy in the nature of mathematical and scientific problems.

- *Single concept problem*: Requires applying a known technique to a problem which is already in symbolic form.

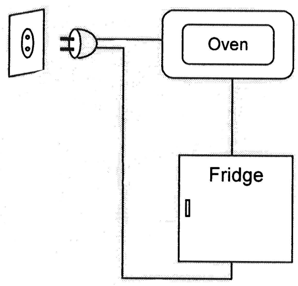
> - Evaluate the integral $\int_0^{\pi/3} \sin^2 x \cos x \, dx$.
> - Format this sentence using 14 point, bold, 'Times Roman' font.
> - A block moves according to the equation $x = 5t - 6t^3$. Where is it after $t = 5$ seconds?

- *Multiple concept problem*: Requires applying two or more techniques to a problem which is already in symbolic form.

> For the function $f(x) = \sin(x^2/2)$ on the interval $(0, \pi)$ find its maximum and minimum values.

- *'Rich context'*[1] *problem*: Requires translating information to and from symbolic representation, determining a strategy, solving the problem, re-translating, and explaining the solution.

Ahmed has decided to use the current flowing from his electrical outlet for not just his 1200 watt oven, but also for his 600 watt refrigerator. By doing so, he believes that he will save money on his electric bill. Here is how he has connected the appliances.



(a) Will this be a valid circuit when the plug is connected to the 220 volt outlet?

(b) Will Ahmed save money?

(c) Will Ahmed be happy with his decision? Support your conclusions with calculations.

A course based on the principle of active engagement tends to focus on the 'rich context' type of problem while providing students with exercises of the first two types for reference.

Teaching problem-solving strategies

This topic alone could consume the entire conference and perhaps it will. As usual, it might be good to offer some good principles and practices.

- Students must learn how to translate words and pictures into sketches, graphs, symbols, and equations. This is particularly difficult, given students' language abilities.
- Explicitly discuss and demonstrate assumptions, conceptual definitions, 'fork in the road' decisions and reasoning. You can do this while students explain their

[1]The term appears in Randall Knight's book, *Five easy lessons: Strategies for successful physics teaching* (2002).

solutions and also by providing limited, judicious demonstrations and handouts (but take care not to give problems that can be solved by using the same exact strategy as you demonstrated).

- Recap important problems by carefully summarising the logical reasoning steps that led to the answer (including the 'blind alleys' that students may have attempted. Students usually think that they are supposed to see the correct strategy on the first attempt).

- Ask students to make up 'cheat sheets' that show the important concepts and equations they have learnt, what they mean, and how they are related. Let them bring one-page (front and back) summaries to examinations. (If you are using rich context problems, the formulae on these sheets will be of limited use as the students will need to know how to apply them using their reasoning skills).

- Examinations and homework should emphasise reasoning and focus on situations and observations (i.e., word problems). Avoid 'show that. . . ' types of problems, except perhaps for mathematics majors, as they are of little or no value in learning to apply concepts and techniques.

- Examinations do not need to cover all of the material, however, students need to know all of the topics that they will be responsible for. Provided that the students do not know which topics will actually appear, a few problems that require reasoning are far better than an encyclopædic series of problems, covering all topics, which require only memorisation and a single formula or technique.

Conclusion

We have covered a lot of ground here, and I am glad that (a) I do not have to write a quiz about what I have presented, (b) you do not have to take the quiz, and (c) there will be no marks given. This would be particularly so if the quiz were of the 'rich context' type, but in a way, when you go back to work at your respective institutions, the quiz begins on its own.

Altering the teaching of mathematics, science, and computer science as I have suggested here is not something that can be done overnight. Doing so will take 'buy-in' from teachers as well as encouragement and support from administrators. Faculty members must have a chance to learn and experiment with these strategies in a protected environment before the strategies are generally adopted. Those who master them and whose students show improved mathematical reasoning knowledge and skills deserve recognition and reward, both from METSMaC and from their home institutions.

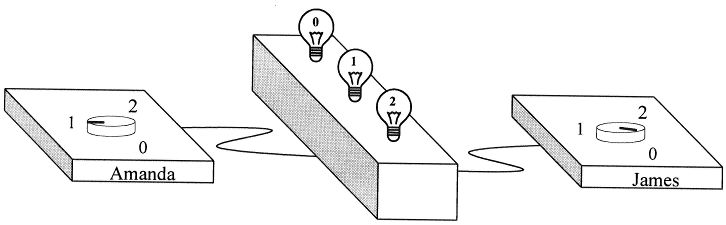
Ultimately, most of us engage in teaching because we enjoy seeing our students succeed. Perhaps we can take a few steps forward and increase our pleasure by making them even more successful in their life pursuits.

Acknowledgements

Much of the material presented here comes from my experiences gained at the United Arab Emirates University's University General Requirements Unit between 2000 to 2002, and in particular, from working with Dr Abdullah Al Khanbashi, Mr Graeme Ward, Mr Yazid Benchabane, and Mr Djamel Bellout. Additional insight comes from teaching physics with two colleagues at California State University, San Marcos, Drs Graham Oberem and Charles de Leone, after I returned to the US. Many of the ideas and techniques presented here come via Prof. Randall Knight of California State Polytechnic University at San Luis Obispo. I commend his book, *Five easy lessons: Strategies for successful physics teaching* (2002), to your attention if you would like to explore further the ideas I have outlined in this paper.

Appendix – The problem of threes

Amanda and James are each given a three-position electrical switch that controls three lights. The switch positions and the lights are labelled '0', '1' and '2' respectively.



The switches and lights work as follows

Amanda	James	Light
0	0	0
0	1	0
0	2	0
1	0	0
1	1	1
1	2	1
2	0	0
2	1	1
2	2	2

Puzzle

1. There is a simple rule that decides which light shines when Amanda and James set their switches. What is the rule? [Hint: It can be expressed in a single sentence.]

2. Suppose that you cannot see Amanda's and James' switches. Light '2' shines. Can you tell how Amanda and James have set their switches? How? If you cannot tell, what are the possible settings of the two switches?

3. Light '1' shines. Can you tell how Amanda and James have set their switches? How? If you cannot tell, what are the possible settings of the two switches?

4. Amanda cannot see James' switch and James cannot see Amanda's switch. By knowing the position of her switch and observing which light is on, is it possible for Amanda to know the position of James' switch? Why or why not?

This problem is based on a nice introduction to the problem of non-binary digital mathematics and number systems (Whealton, 2005).

References

HELLER, P. M. (2005). *University of Minnesota physics education research and development* [online].
Available from: `http://groups.physics.umn.edu/physed`

KNIGHT, R. (2002). *Five easy lessons: Strategies for successful physics teaching*. Addison Wesley: New York.

WHEALTON, S. (2005). *Number wars: The battle between 2 and 3* [online].
Available from: `http://www.washingtonart.net/whealton/wars.html`

Effective learning strategies for mathematics education

Glenda Anthony

Department of Technology, Science and Mathematics Education, Massey University, Palmerston North, New Zealand

Current reforms in mathematics education, founded on sociocultural models of teaching and learning, position students as active members of a community of practice. While learning mathematics has always involved engaging in strategic learning behaviours, reform classrooms increasingly expect that students actively participate in their own learning through collaboration, communication, and sense-making practices – practices that require students to engage in self-regulated strategic behaviours and to monitor their progress in using these strategies. Although some students naturally develop an effective and appropriate range of learning strategies, this paper argues that more explicit support through task selection, classroom discourse, and modelling of effective strategic learning behaviours, be they cognitive, affective, metacognitive, or resource management focused, is needed to ensure that *all* students learn mathematics effectively.

Introduction

Learning mathematics is an active process involving exploration, formalisation and assimilation (Mason and Johnston-Wilder, 2004). Using strategic learning behaviours learners must appropriately control their learning processes by selecting and reorganising relevant information and building connections from existing knowledge. Students' use of learning strategies has emerged as a critical variable in the learning process, affecting what is learnt in terms of content, dispositions, and values (Wang, Haertel and Walberg, 1993; Vermunt and Vermetten, 2004).

Influenced by a range of sociocultural learning theories (e.g., Sfard, 2000; Wenger, 1999; Yackel and Cobb, 1996) current mathematics education reforms attend to the intrinsically social and cultural nature of cognition, including how the social environment is organised and how students participate in social practices. New reform goals, emphasising conceptual understanding, strategic competence, adaptive reasoning, productive dispositions, and procedural fluency (Kilpatrick, Swafford and Findell, 2001)

require students to actively engage in strategic learning behaviours and regulate their thinking. These goals raise important questions with regard to the practices students participate in and the actions taken by teachers (Goos, 2004). This paper argues, along with others (e.g., de Corte, Verschaffel and Eynde, 2000; Pape, Bell and Yetkin, 2003; Wilson and Clarke, 2004), that explicit support is needed to develop students' effective strategic learning behaviours in the mathematics classroom.

Learning strategies in mathematics

Definitions of learning strategies within the literature are broad based. Learning strategies are considered to be those behaviours that we invoke in the learning process to intentionally influence the form and quality of the knowledge we acquire. For example, when we learn mathematics the activities we engage in and our associated strategic behaviours have the potential to enhance our understanding or help us remember a formula or rule. When reading a mathematics example, one might, for instance, think about how the example relates to an earlier example or ask, 'What if this value were negative instead of positive?' One might stop to inquire, 'Do I understand where this line comes from?' If not, one might re-read the information in the text, or try to rework the example on paper.

Learning strategies possess the following four characteristics: goal orientation; intentionality; effortfulness; and performance enhancement (Garner, 1990). The goal of a learning strategy is to 'affect the learner's motivation of affective state, or the way in which the learner selects, acquires, organises, or integrates new knowledge' (Weinstein and Mayer, 1986, p. 315). Goals can usefully be classified according to cognitive, affective, metacognitive or resource management outcomes – outcomes that are largely determined by the nature and demands of the learning task, and mediated by the students' metacognitive knowledge related to their beliefs about themselves as mathematics learners.

Cognitive strategies include: rehearsal strategies, such as practice, re-reading and revision; elaboration strategies, such as linking new information with prior information, imaging, comparing, generating or answering questions related to conceptual understanding, and seeking or generating explanations; and organisational strategies, such as summarising, notating, and formatting information.

Metacognitive strategies, such as planning, repetition, selective attention and evaluation, control and monitor the learning process. For example, a student may evaluate a solution procedure based on the criteria of 'ease of computation', 'understanding versus rule following', or 'efficiency'.

Affective strategies such as self-talk, self-praise or reward, are employed to enhance one's concentration, reduce anxiety, or to maintain effort and self-esteem.

In contrast to internally-oriented strategies, external resource management strategies, such as peer cooperation, help seeking, or task or environment management, operate directly on the learning environment. As such, they may be self-directed or teacher–

peer directed. For example, a student may modify the task challenge by imposing a time limit or attempting the harder problems, and a teacher may facilitate peer collaboration through setting arrangements.

Within mathematics education, research involving learning strategies has principally been associated with student behaviour (Anthony, 1994, 1996a, 1996b; Wong and Herrington, 1992), especially metacognitive behaviour in the context of problem solving (Goos, Galbraith and Renshaw, 2004; Wilson and Clarke, 2004), and self-regulated learning (Pape et al., 2003).

Students' use of learning strategies

Clearly the strategic approaches that students use in any one instance are varied and linked to numerous factors such as prior knowledge, the nature of the task, motivation, availability of resources, classroom pedagogy and norms. While learning mathematics has always involved engagement of strategic learning behaviours, research studies in mathematics classrooms (Anthony, 1994; Boaler, 1999; Pape et al., 2003; Wilson and Clarke, 2004) found that the range and quality of students' strategic learning behaviours vary, and in some cases were ineffective in assisting students' knowledge construction processes.

Anthony's (1996b) case studies of two senior secondary students' learning behaviours illustrate that although both students were actively involved in the classroom activities and both students believed they were pursuing learning in mathematics, the way in which they went about the learning process clearly influenced their respective learning outcomes. The actions of the first student, Gareth, were consistent with Bereiter's (1990) description of a 'schoolwork module'. He focused on activities as work to complete and his involvement in the social practice of the classroom reflected an adaptive way of interpreting the learning environment. Gareth's learning strategies, directed at task completion rather than the development of conceptual understanding, involved unaltered encoding, or mental recycling of the teacher given information. As a consequence, Gareth's mathematical knowledge and skills tended to be inert, and available only when clearly marked by context.

In contrast, a second student, Adam, organised his learning environment around goals of personal knowledge construction. An 'intentional learner', Adam's self-regulatory strategies of goal planning, and monitoring enabled him to select appropriate learning strategies. He regularly monitored his comprehension and developing understanding, self-tested by generating and working through similar problems (meaningful practice), anticipated answers to teacher's questions, and checked his own answers against those of the teacher as well as those of the other students. Awareness of cognitive conflict or difficulties facilitated appropriate remedial strategies including an effective range of help strategies.

Instructional influences

The multitude of interrelated factors that affect student learning can be broadly grouped into student, context and instructional factors. Student factors include prior domain knowledge, metacognitive knowledge, learning goals and affect. Contextual factors include the physical learning environment, the social and cultural nature of learning (peer interactions, discourse, etc.), and the availability of resources. While not dismissing the significant influence of both student and contextual factors, the following aspects of the classroom/lecture environment – task demands, worked examples, assessment practices, and classroom norms – have been selected as a framework to exemplify how learning strategies can be influenced, both positively and negatively by instructional factors.

Task Demands: Tasks provide the context in which students learn to think about mathematics: they convey messages about what mathematics is and what doing mathematics involves. In classrooms where the majority of the seat-work time involves exercises mimicking teacher-provided examples, the task focus is on computational procedures and accuracy, with repetitive practice promoted as the key strategy to successful outcomes. Typically, those students engaged in a 'complete exercised 1a, followed by 1b' pattern know in advance which computational procedures are required to solve the exercises and thus their learning strategies focus on recall of how the teacher (or oneself) did a similar problem rather than elaboration, and organisation of ideas. While repetition is a helpful and necessary learning strategy, practice activities should be meaningful and integrated with learning for understanding (Anthony and Knight, 1999).

When confronted with difficult tasks or when the answers are not readily available, student resistance to task engagement through downward negotiation of task demands is a characteristic behaviour within some classrooms (Anthony, 1996a; Goos et al., 2004; Henningsen and Stein, 1997). Unfortunately, if the balance between task demands, instructional support, and compensatory behaviour is undermined, or teachers unwittingly reduce cognitive load by subdividing tasks, setting short-term learning goals, or providing additional informational products, the need for strategic learning behaviours is diminished. For example, the teacher supply of specific items in a test, keywords, tables and topic summaries, which students would otherwise be expected to generate, although intended to support student learning, in reality compensate for student learning. Strategies of organisation and selective attention involved in summarising, note-taking and recording information are essential practices for senior students. Failure to develop and appreciate the benefits of these strategies for learning and revision mean that many tertiary students mindlessly record all that is written on the lecture overheads, or try to revise from unwieldy and disorganised notes (Anthony, 2000). An alternative to these compensatory supports would be to provide orienting information (e.g., a list of content areas to be responsible for), a model for a process (e.g., a table to complete), or a concept map or flow diagram from which the student would form a

summary.

Other practices regularly employed by students to reduced cognitive load when completing tasks included copying work from others, answering questions using prompts from other students or the textbook answers, or offering provisional answers (guesswork) to indicate apparent engagement in the task. In inquiry-based classrooms where expectations for student explanation and justification are established these practices are less viable. Often such classrooms encourage collaborative working norms where students working in groups monitor progress, seek feedback on ideas, and explain ideas to each other before reporting back to the whole class (Goos, 2004).

Worked Examples: The presentation and student interpretation of worked examples may, or may not, promote effective strategic learning. Stimulated recall interviews with secondary students by Anthony (1996a) revealed a relative absence of self-questions related to the conceptual nature of teacher-provided worked examples; instead student attention was more likely to be directed to the acquisition of specific information needed for the algorithmic activity. In effect, students sabotaged the instruction by selecting from it only the minimum necessary to answer the teacher's questions and achieve correct performance. More successful students, however, did attend to the underlying structure of the worked example and used discussion as an opportunity to self-question and generate self-explanations. These self-explanations have the characteristic of adding tacit knowledge about the actions of the example solution, thus inducing greater understanding of the principles involved.

A similar scenario is enacted in the lecture situation where there is strong reliance on worked examples. In an effort to meet student demands for more worked examples (Anthony, 2000), it may be tempting to provide examples of every type that students will meet in assessment. However, Mason (2002) warns of over indulging the student: 'the more comprehensive the worked examples provided, the easier it is for students to repeat the format, but the more likely they are to miss the provider's intention, and fail to appreciate the generality' (p. 78). Some students who 'follow' the lecture examples are lulled into an unrealistic self-assessment of their understanding and see little need to engage in any further problems other than the compulsory assignment questions, as would be expected to consolidate, test and refine their understanding. Suggestions for promoting more effective learning behaviours when using worked examples include questioning that stimulates elaboration, providing opportunities for students to specialise and generalise, using prompting type questions (e.g., 'What question should you be asking when you are stuck?') rather than direct questions (e.g., 'How is this example different or similar to the previous example?'), providing students with time in lectures to construct and work through a similar 'problem type', and notating the process alongside each line of the example. These instructional techniques encourage student employment of cognitive and metacognitive strategies that will enhance their learning.

Assessment: At all levels of mathematics learning, assessment has a crucial influence on student learning. Wiliam (2001) contends that formative assessment, in the

form of rich questioning, feedback, and student involvement in their own learning, has the power to be beneficial for all students – particularly low attainers.

Rich questions enable the teacher to explore student thinking and provide evidence of what the teacher needs to do next in order to broaden or deepen student understanding. In inquiry-based classes, the use of rich questions facilitates students' strategic engagement in the evaluation of the adequacy of specific knowledge, making connections, clarifying, elaborating and, building alternatives (Goos, 2004). Contrast this to a situation where the teacher regularly prompts, self-answers, and provides limited wait time. Anthony (1994) noted that low-achieving students, in particular, were often interrupted with a prompt or the answer, rather than guidance, when they hesitated or responded incorrectly.

Teacher: *What is the thing inside the square root called? Can anyone remember – it begins with v?*

Dean: (calls out) *Velocity.*

Teacher: *Variance, not velocity. You may be asked to find the variance in the test.*

If a teacher regularly answers his or her own questions, the need for students to engage in cognitive processing, reflection and self-assessment is diminished. The risk that students learn that non-answers quickly generate teacher prompting and that they need not engage in sense-making is very real. Stimulated recall interviews did, however, reveal that students sometimes answered questions privately; fuelled perhaps by the expectation that others or the teacher would answer, or an unwillingness to engage in public discussion.

> I noticed that she (teacher) forgot to times by $n/2$ but I didn't really want to speak out because I feel like, because I thought someone else might pick it up as well. [Adam, in Anthony, 1994]

The nature of feedback is also a significant factor affecting students' selection and use of learning strategies. Feedback from formative assessment – the provision of information fed back to the learner that is used by the learner to improve their future performance – has been shown to be particularly effective (Wiliam, 2001). While feedback may principally involve information about students' mathematical knowledge and skills, it should also include information about students' approaches to learning. Teachers' understanding of the propensities of their students in regards to studying can 'inform actions aimed at drawing pupils into classroom work and steering their approaches to study' (Ruthven, 2002, p. 182). Improved performance is possible when students reflect on the multiple causes responsible for their learning outcomes: success experiences provide information regarding task-appropriate strategies, whereas failure provides feedback regarding task-inappropriate strategies.

Formal assessment, often summative in nature, that is dominated by questions requiring repetition of teacher-given procedures effectively reduces the demand for high-level thinking, causing students to modify their revision strategies accordingly.

> It's more of a concern to know how to get the right answers because you don't really get checked much on understanding, all you get is a list of problems in the test. [Gareth, in Anthony, 1994]

Students in Anthony's research gained information about the structure and content of each test from teacher cues and revision of previous years' papers. The predictability of the test content and structure encouraged passive learning: revision involved a quick flip through the class examples and teacher-provided summaries, and reliance on teacher-directed study the day before the test. There was little encouragement for students to identify and evaluate their own particular learning needs. Anthony (2000) also noted first-year tertiary students' expectations that exam material should mirror that found in assignments:

> I think it's the lecturer's job to give me the important information I need for the examinations, rather than find it in the study guides. [Student]

In more formal test situations, mathematics tests are usually returned with marks. In the traditional class format, Anthony (1994) noted that teacher feedback and student interest focused on the product, rather than the learning process. Recent moves in New Zealand secondary schools towards outcomes-based assessment practices in mathematics include the sharing of marking criteria and exemplars with students in order to negotiate what counts as quality.

Classroom norms: Classroom norms and associated learning orientations affect strategic learning behaviours. Students constantly construct interpretations of their teacher's behaviours and expectations, and the nature and purpose of classroom activity. In classrooms that emphasise task mastery, goals and understanding, success is seen as dependent on effort and strategic behaviours. In classrooms that emphasise ego, ability and performance orientations, students are socialised with the goal of getting good grades, being judged able, and feeling success is dependent on ability.

In performance-oriented classes, the teacher focus on maintaining the pace is typical. Several students in Anthony's (1994) study expressed concern that they moved onto new topics before they sufficiently understood the old ones, that it was difficult to 'keep up', and that you had to memorise lots of material and rules. Associated 'funnelling' type questioning (Wood, 1998) that encouraged unreflective answers were the norm. Anthony observed that less successful students often related public help-seeking or contributions to discussions to feelings of personal inadequacy and a wish to avoid comparison with other students:

> Some of the time I don't understand the stuff enough in mathematics to answer questions 'cause I'll probably get it wrong. I only answer questions if I know the answers. [Jane, from Anthony, 1994]

Students' unwillingness to answer teacher questions unless they are confident that they already know the sought-after response is a direct result of questioning norms that focus on right answers. For some students unresolved conflicts may reinforce doubts about themselves, undermining their autonomy as mathematics learners:

> I didn't think Faye's answer of histogram was right. I think about other student's answers but I wait for the teacher to confirm it as well . . . I'm pretty sure Kane's right because she's writing it on the board. I was thinking I've really bummed out because it's not what I had. [Karen, in Anthony, 1994]

Opportunities for students to direct their own learning encourages them to use and evaluate a range of learning behaviours. In the traditional class studied by Anthony (1994) instructional demands tended to be very structured. While the intent may have been to support and guide learning, students were in fact given little encouragement or opportunity to preview material, explore the text, or generally take responsibility for directing their own learning. On one occasion a student had completed the required task and was working independently; when the teacher checked his progress she immediately set an alternative task, disregarding the student's self- selected work.

> She (teacher) said read estimation. I thought she would just come to see what I was doing. I didn't know she would tell me to read something else (surprised tone). It doesn't matter. I can do that at home sometime – it doesn't worry me. I've already done the work on estimation, but I didn't tell her, so it will be like revision anyway. [Adam, in Anthony, 1994]

Instructional cues which allow students to anticipate learning activities also influence learning behaviours. Teachers sometimes use a technique of going around the class for answers to a set of problems. While the intent may be to encourage participation, students in Anthony's study reported concentrating only on thinking of an answer for 'their turn' – a practice that interfered with the process of evaluating other students' responses.

In inquiry classrooms teachers help students make sense of the mathematics by asking questions that prompt students to clarify, elaborate, justify and critique their own and each other's assertions. Elaboration processes of linking and comparing can be supported with questions that move students' thinking either forwards to new ideas ('How is this related to J's assertion?') or backwards towards prior knowledge ('How is the cosine rule related to Pythagoras theorem?'), or can serve to consolidate students' thinking by linking the ideas developed during the lesson ('What did you divide by in the previous example?') When students are 'authorised to make sense of the mathematics in ways that are meaningful to them they have a sense of themselves as able to go beyond the given to forge new ways-of-being in mathematics' (Klein, p. 2002). The verbalisation of their processes and the reflection on their thinking are behaviours that simultaneously support effective learning strategies and encourage mathematical thinking. This sharing of responsibility for authenticating and appropriating mathematical

knowledge contrasts with the norms of those classes where students rely on the text-book answer, or the teacher, as the source for revealing correctness. In this situation students receive limited information about the way they tackled the task.

Discussion and implications

These classroom episodes highlight the influence of instructional orientation and organisation in shaping – and reshaping – students' strategic learning behaviours. The repeated actions which both students and teachers engage in as they learn are important 'not only because they are vehicles for students' knowledge development, but because they come to constitute the knowledge that is produced' (Boaler, 2002, p. 113). When instruction and assessment revolve around the end product of the task, students are encouraged to view learning in terms of 'doing' or 'completing' a task and they select their learning strategies accordingly. Adaptation to classroom routines in which students focus on activities as work and on completion and production rates means that learning is marginalised and becomes no more than coincidental with school-work. Moreover, in learning situations where students are able to persuade the teacher to be more direct, and to lower the ambiguity and risk of tasks, instruction inadvertently mediates against the development and use of appropriate and effective learning strategies. When this situation is compounded with assessment structures that encourage the use of learning strategies appropriate for rote memorisation and recall of previously-seen examples, there is limited incentive for students to develop self-regulated learning strategies – strategies that are so necessary for tertiary study.

In addition to the direct instructional effects, students' unique interpretations of their learning environment affect their learning approach. Although studying alongside one another in the same classroom, the two case study students, Adam and Gareth (Anthony, 1996b), projected themselves into distinctly different mathematical environments. In general terms, their approaches exemplify the distinction between study approaches that lead to 'deep' and 'surface' learning (Marton and Booth, 1997). For Gareth, who perceived the improvement in his mathematics learning as a matter of 'working harder', it was clear that what he needed was help to 'work smarter', pursuing those strategies that underpin a deeper approach to learning mathematics. While most students want to learn with understanding and value cooperation and the sharing of ideas, to do this successfully we need to provide a learning environment that supports the awareness and development of a wide range of effective learning strategies.

A deeper approach to studying mathematics is advocated in the mathematics reform literature that promotes classroom norms supporting social interaction, reflective discourse and co-construction of knowledge and values. In particular, students are expected to develop multiple strategies to solve problems and provide explanations and justifications for their solution strategies and mathematical thinking. However, establishing such a learning environment is not necessarily straightforward (Goos et al., 2004). A caution is noted in Ruthven's (2002) discussion of classroom assessment is-

sues. He identifies two major dimensions of assessment which can inform teaching actions: a dimension concerned with understanding the propensities of students as regards studying and a dimension concerned with charting the progress of students towards curricular objectives. However, Ruthven contends that such actions are aligned with teacher beliefs of ability. Only those teachers who perceive ‘ability as an evolving and malleable state, a convenient encapsulation of a matrix of cognitive and metacognitive capabilities remaining open to development’ (p. 182) are likely to develop pedagogic practices associated with improvement of students’ strategic learning behaviours.

For my part, I would argue that the promotion of learning strategies in the mathematics classroom must start with the legitimisation of learning strategies as a topic of classroom conversation. In relation to enacting reform practices in the mathematics classroom, Pape et al. (2003) contend that ‘the invisible nature of much of what is assumed within the community of practice is often not made visible to those who exist furthest for these practices’ (p. 181). Consequently, we need to make descriptions regarding the cognitive processes and strategic behaviours more explicit for students. In tandem with instruction that focuses on students’ sense-making, we must also model, teach and discuss a wide range of learning strategies *and* provide students with feedback on their use of strategies. Effective strategic learning behaviours cannot be left to chance, employed by a few, they need to be encouraged and supported to enable *all* learners in our mathematics classrooms to more fully participate in communities of practice.

References

ANTHONY, G. (1994). *Learning strategies in mathematics education*. Unpublished PhD thesis. Massey University: Palmerston North.

ANTHONY, G. (1996a). When mathematics students fail to use appropriate learning strategies, *Mathematics Education Research Journal*, **8**(1), 23–37.

ANTHONY, G. (1996b). Active learning in a constructivist framework, *Educational Studies in Mathematics*, **31**(4), 349–369.

ANTHONY, G. (2000). Factors influencing first year students’ success in mathematics, *International Journal of Mathematics Education in Science and Technology*, **31**(1), 3–14.

ANTHONY, G. AND KNIGHT, G. (1999). The role of practice in mathematics learning, *The Mathematics Educator*, **4**(2), 91–107.

BEREITER, C. (1990). Aspects of an educational learning theory, *Review of Educational Research*, **60**(4), 603–634.

BOALER, J. (1999). Participation, knowledge and beliefs: A community perspective on mathematics learning, *Educational Studies in Mathematics*, **40**(3), 259–281.

BOALER, J. (2002). The development of disciplinary relationships: Knowledge, practice, and identity in mathematics classrooms, in A. Cockburn and E. Nardi (Eds), *Proceedings of the 26th Conference of the International Group for the Psychology of Mathematics Education* (Vol. 2, pp. 113–120). PME: Norwich.

DE CORTE, E., VERSCHAFFEL, L. AND EYNDE, P. (2000). Self-regulation: A characteristic and a goal of mathematics education, in M. Boekaerts, P. Pintrich and M. Zeidner (Eds), *Handbook of self-regulation* (pp. 687–726). Academic Press: San Diego.

GARNER, R. (1990). Children's use of strategies in reading, in D. Bjorklund (Ed.), *Children's strategies: contemporary views of cognitive development*. Lawrence Erlbaum Associates: Hillsdale.

GOOS, M. (2004). Learning mathematics in a classroom community of inquiry, *Journal for Research in Mathematics Education*, **35**(4), 258–291.

GOOS, M., GALBRAITH, P. AND RENSHAW, P. (2004). Establishing a community of practice in a secondary mathematics classroom, in B. Allen and S. Johnston-Wilder (Eds), *Mathematics education: Exploring the culture of learning* (pp. 91–116). RoutledgeFalmer: London.

HENNINGSEN, M. AND STEIN, M. (1997). Mathematical tasks and student cognition: Classroom-based factors that support and inhibit high-level mathematical thinking and reasoning, *Journal for Research in Mathematics Education*, **28**(5), 524–549.

KILPATRICK, J., SWAFFORD, J. AND FINDELL, B. (Eds). (2001). *Adding it up: Helping children learn mathematics*. National Academy Press: Washington, DC.

KLEIN, M. (2002). Teaching mathematics in/for new times: A poststructuralist analysis of the productive quality of the pedagogic process, *Educational Studies in Mathematics*, **50**(1), 63–78.

MASON, J. (2002). *Mathematics teaching practice: Guide for university and college lecturers*. Horwood Publishing: Chichester.

MASON, J. AND JOHNSTON-WILDER, S. (Eds). (2004). *Fundamental constructs in mathematics education*. RoutledgeFalmer: London.

MARTON, F. AND BOOTH, S. (1997). *Learning and awareness*. Lawrence Erlbaum Associates: Mahwah.

PAPE, S., BELL, C. AND YETKIN, I. (2003). Developing mathematical thinking and self-regulated learning: A teaching experiment in a 7th-grade mathematics classrooms, *Educational Studies in Mathematics*, **53**(3), 179–202.

RUTHVEN, K. (2002). Assessment in mathematics education, in L. Haggarty (Ed.) *Teaching mathematics in secondary schools* (pp. 176-191). RoutledgeFalmer: London.

SFARD, A. (2000). Steering (Dis)course between metaphor and rigor: Using focal anal-

ysis to investigate the emergence of mathematical objects, *Journal for Research in Mathematics Education*, **31**(3), 296–327.

VERMUNT, J. AND VERMETTEN, Y. (2004). Patterns in student learning: Relationships between learning strategies, conceptions of learning, and learning orientations, *Educational Psychology Review*, **16**(4), 359–384.

WANG, M., HAERTEL, G. AND WALBERG, H. (1993). Toward a knowledge base for school learning, *Review of Educational Research*, **63**(3), 249–294.

WEINSTEIN, C. AND MAYER, R. (1986). The teaching of learning strategies, in M. Wittrock (Ed.) *Handbook of research on teaching* (pp. 315–327). Macmillan: New York.

WENGER, E. (1999). *Communities of practice: Learning, meaning and identity*. Cambridge University Press: Cambridge.

WILIAM, D. (2001). Formative assessment in mathematics, in L. Haggerty (Ed.), *Aspects of teaching secondary mathematics* (pp. 273–284). RoutledgeFalmer: London.

WILSON, J. AND CLARKE, D. (2004). Towards the modelling of mathematical metacognition, *Mathematics Education Research Journal*, **16**(2), 25–48.

WONG, K. Y. AND HERRINGTON, T. (1992). Research in learning strategies in mathematics, in B. Atweh and J. Watson (Eds), *Research in mathematics education in Australasia 1988–1991* (pp. 129–142). Mathematics Education Research Group of Australasia: Kelvin Grove.

WOOD, T. (1998). Alternative patterns of communication in mathematics classes: Funneling or focusing?, in H. Steinbring, M. Bussi and A. Sierpinska (Eds), *Language and communication in the mathematics classroom* (pp. 167–178). National Council of Mathematics Teachers: Reston, VA.

YACKEL, E. AND COBB, P. (1996). Sociomathematical norms, argumentation, and autonomy in mathematics, *Journal for Research in Mathematics Education*, **27**(4), 458–477.

The systematic design of learning

Nancy Schley

Madison Area Technical College, Madison, Wisconsin, United States of America

Introduction

Would it not be wonderful if teachers were so well prepared for a class that all the learning activities were written out, all the assignments designated, all the handouts duplicated, all the assessments laid out with designated criteria and grade points valuation for the learners to use? Would it not be wonderful if, with all this documentation completed long before the class started, we, as teachers, could concentrate on research to stay at the cutting edge of our field and/or spend our time helping learners through their problems or have time to prepare enrichment exercises to push our learners towards excellence? Would it not be wonderful if all teachers in the same classes were teaching the same programme and learning outcomes? Would it not be wonderful if our assessments were so well written and documented that we could tell our learners, other faculty, administration, future employers, and supervisors exactly what our learners learnt, when and how?

This utopia can all be possible if we, as teachers take the time to plan the learners' learning long before we enter the classroom to teach. The systematic design of the learning process that I am going to propose is one proven way to develop all the pieces of the course curriculum that fit with these goals. Then, as our classes proceed, we write down what worked, what did not work, and how to change or adjust our activities/goals/assessments at the end of each class period so we are totally prepared to teach in the next assigned teaching cycle.

This paper is an explanation of a process that we use to design and develop standardised documents as deliverables to all involved in the design and development of a course.

Learning by design

When faced with the task of systematically designing curriculum, we encounter typical learning design problems. We normally ask such questions as:

- **Who** are my learners and what do they need to learn?
- **What** will I teach?
- **How** should I teach the content?
- **How** will I evaluate the learners' work?
- **When** will I know the learners have learnt?

When developing curriculum, we follow the principle of Performance Based Learning (PBL). This principle relies on learner performance or demonstration of the application of skills, knowledge, and attitudes. It measures learner achievement based on performance standards developed by the teacher(s). This strategy allows learners to progress only when they have achieved the stated goals. It also holds learners and teachers accountable for the achievement of the intended outcomes.

Two major challenges of the Performance Based Learning design are finding time for up-front planning and developing expertise at measuring performance rather than knowledge. To measure this performance adequately, we need to determine performance expectations for learners, design assessments that measure the performance, and then align learning activities with the performance expectations and assessments.

Why do we design learning based on performance? Because we are entrusted to help learners build the skills, knowledge, and attitudes they need to succeed professionally and personally, and to deliver excellence in teaching and learning – in all learning environments (classroom, online, lab, workplace, etc.); and we need to infuse industry standards to better prepare a high performing workforce. But do not kid yourself; designing learning based on performance is hard work!

As a teacher, it is important to be able to recognise the elements and characteristics of performance-based learning design. The performance-based-learning curriculum development model has fourteen steps including:

- Analyse the needs of the learners
- Develop programme outcomes
- Develop course information
- Write competencies (course outcomes)
- Sequence the competencies so they flow in a learning hierarchy
- Designate core abilities and link them to the competencies
- Specify assessments strategies
- Develop assessment criteria

- Write learning objectives
- Design learning activities
- Select learning plan prerequisites
- Develop instructional materials
- Write teaching plans
- Create a course syllabus

Before we begin to design courses, we need to determine program outcomes. Programme outcomes indicate what a student will be able to do with the knowledge, attitudes, and behaviours they acquired as a result of taking all the courses in the programme. We use a process promoted by Steihl and Lewchuk (2002, 2005); modelled after the business world's affinity chart. We gather faculty, learners, graduates, and other stakeholders as an advisory board and ask the question: 'What do our learners need to know and do out there that we can teach them in our school?' This group privately brainstorms ideas, writing each on a post-it note and arranging them under three headings: concepts (the knowledge in the field), skills (what must be done in the field), and issues (ethics, communication, business, management). Next everyone comes together to classify the individual ideas into groups of like thoughts. We then write a programme outcome statement for each grouping. We continuously refine these statements until they express exactly the appropriate outcomes for each programme.

After we have developed the programme outcomes, we work at the course level following the same process. At this point the advisory board may or may be not included in producing the course outcome statements.

After we have developed the course outcomes, we list the topics that need to be covered each week in the course. We then sequence topics by developing a learning hierarchy, arranging what must be learnt first (listed at the top), what must be learnt next is second, etc. It is wise to write topics on post-it notes to quickly move them around.

Next we write all the pertinent information about the course such as the course name, number, developer(s), development date, credits, etc. Then, the teachers (or teacher depending upon whether more than one teacher teaches the same course) write what we call competency statements dealing with what is to be covered in the course. A competency can be defined as a major skill, knowledge, attitude or ability needed to perform a task. It is measurable and observable. It describes what the learners will be able to do as a result of the learning process so the statement begins with a verb.

Core abilities and programme outcomes are then selected and linked to the competencies. Core abilities are skills that learners need to be successful in the workplace and in all areas of their lives. Examples of these skills include: communicate effectively, demonstrate critical thinking, develop a sense of personal, social, professional,

and work ethics, develop global awareness, use mathematics effectively, use science and technology effectively.

Assessment

The next step in this design is to consider how to assess the learners in the course. Notice that we prepare the assessment tasks before we talk about what will be going on in the classroom. This way we can keep the 'end in mind' as we later prepare learning activities for the learners. As a note of clarification: assessment means ongoing, individualised feedback given in a constructive manner for continual improvement. We believe that learners learn better when they receive continuous feedback about their progress. Evaluation is closure, the final grade, if you will.

We write the instrument or measurement that will be used to assess each competency (called a condition). Examples of conditions include: by completing a written product, by contributing in class discussions, in clinical performance, through homework assignments, on a lab report, in a presentation. Only after identifying the condition can we write the criteria for assessing this measurement. The criteria describe satisfactory performance and provide the basis for judging whether or not the performance is accepbable. Indicating to the learners upfront how their performance will be judged is extremely important. So, we tell the learners the expectations for acceptable performance – no surprises and no more learner guessing what the teacher wants at the beginning of the assessment. Because learners see how they will be evaluated, they focus their time and energy to prepare better performances or products and self-assess their work before submitting it for formal evaluation or grading. They are therefore, more likely to perform according to the teacher's expectations. When they do not achieve, they are empowered to assess their own work and make corrections or seek assistance prior to evaluation. For teachers, the criteria offer a precise measuring tool for assessing and evaluating achievement consistently and for accountability documentation. Examples of criteria are: You select an issue that is important and relevant to each institution. You outline a personal position on the issue. The presentation purpose is clear. The presentation includes an introduction with an overview of the main points. The presentation includes a conclusion.

Next we create the performance assessment task. Performance assessment is the process of determining whether the learners perform the intended competencies (the evaluation process). The performance assessment task involves taking the condition and criteria already written and applying a rating scale to them. The rating scale is a pre-established, fixed value used to differentiate among levels of performance. This task can be used as a learner feedback mechanism for assessment or for evaluation.

Classroom practice

Now, finally we decide what we do in the classroom. We design learning plans that include learning objectives and learning activities that prepare the student for assessment and evaluation. The *Learning Plan* is communicated to the student at the beginning of the lesson or course, creates a structure that learners can follow, and is a clear connection between competencies, learning, and assessment. The learning activities provide a step-by-step guide to the learner through the learning experience. In other words, a Learning Plan links *what* learners will learn with *how* they will learn and *when* they will know they have achieved competence (Mashburn and Neill, 2002).

We begin by designing learning objectives that guide the learners through what is going on in the classroom as the learning environment. These reflect measurable and observable supporting skills, knowledge, and attitudes needed to perform each competency. Then we design the learning activities to guide learners through the learning process. The learning activities feature learner-centred activities, require frequent practice, include a variety of learning/teaching strategies, and relate directly to the competency

In using the Performance Based Learning principle, we consciously avoid the traditional lecture, read, question, test for information process. It does however not mean we eliminate all of these. It means including participative learning activities that offer learners opportunities to work in their preferred mode of learning. Demonstrations, simulations, investigations, guided practice and projects are all examples of these activities. We can also vary the learning environment to include classroom, lab, community, and the workplace along with individual and collaborative learning that call for interpersonal contact such as working in pairs, small groups, or large groups. Finally, we can vary the media such as computer simulations, satellite conferencing, the Internet, slides, video, demonstrations, manipulations, models, and hands-on practice.

We finish the learning plan with an application exercise that allows the learner to apply what they have learnt to real world situations. We, then select and/or develop instructional materials including assignments, information handouts, and interactive learning objects as needed.

Lastly, we create a class syllabus that includes teacher information, course information, policy statements, and a learning schedule. The syllabus serves as a guide from the beginning to the end of the course.

Conclusion

In conclusion, when we, as teachers spend time designing quality learning in a systematic way, we design from the top down, concentrating on the learning outcomes, establishing learner assessment tasks, and finally generating activities for the learning environment that prepare our students for the assessment/evaluation. The learners, however, concentrate on the learning first, then the assessment and finally realise the achievement of the learning outcomes, just the opposite of how we design our courses.

If we plan and design our curriculum in a systematic way, our learners will achieve the learning outcomes for each course.

References

Accelerated learning course builder (1999). The Center for Accelerated Learning: Wisconsin.

ANGELO, T. A. AND CROSS, K. P. (1993). *Classroom assessment techniques: A handbook for college teachers* (2nd ed.). Jossey-Bass Publishers: San Francisco.

MASHBURN, D. AND NEILL, J. (2002). *WIDS learning design system user's manual* (Version 7). The Wisconsin Technical College System Foundation, Inc.: Wisconsin.

STIEHL, R. AND LEWCHUK, L. (2002). *The outcomes primer: Reconstructing the college curriculum*. The Learning Organisation: Oregon.

STIEHL, R. AND LEWCHUK, L. (2005). *The mapping primer: Tools for reconstructing the college curriculum*. The Learning Organisation: Oregon.

Oral and Poster Session Papers

Mathematics

Constructing an effective mathematics learning environment for ESL students

Graeme Ward

Foundation Mathematics, The Petroleum Institute, Abu Dhabi, United Arab Emirates

The issues involved in developing and implementing an effective student-centred, problem-based mathematics learning-environment for ESL students are discussed. We look briefly at the forces currently shaping the teaching and learning of mathematics, the history surrounding these influences, and at the evolution of the teaching and learning practices of mathematics in a typical ESL environment (in this case The Petroleum Institute, Abu Dhabi, United Arab Emirates) in response to these forces.

Introduction

The teaching and learning of mathematics has undergone profound changes in recent decades. The emergence and acceptance of the constructivist theory of learning that 'all knowledge and understanding is constructed from previous knowledge and experience' (von Glaserfeld, 1990), has led to a major change in the teaching of mathematics and in the development of mathematics curricula. The learning style and the 'multiple intelligences' of the individual learner, have become a critical issue in the presentation and dissemination of mathematical knowledge, skills and understanding. No longer are learners viewed as empty vessels waiting to be filled with 'facts and figures'. The individuality of every learner, his/her past experiences, successes and failures in learning are seen as complementing, facilitating, even barring, the effective construction of knowledge and the development of skills, understanding, and iteratively, appreciation. The uniqueness of every learner has meant educational theorists and those who teach, have had to categorise and summarise student learning-styles (Fraser, 1998) and develop materials and approaches that are equitable and egalitarian. For the classroom teacher this has meant diversification of presentation into what has been termed 'differentiated instruction'.[1]

[1] See, for example: `www.ascd.org/pdi/demo/diffinstr`

Coupled with this change in perspective, has been the third technological revolution. The 'information age' has seen a massive growth in the amount of knowledge available to society and greater access to this information. No longer are people required to store vast amounts of information but can instead access and apply (the majority) using technology. Students, in particular, are no longer required to memorise vast tracts of often meaningless facts. No longer storehouses of information, they are now consumers of information with rapid access to huge stores of organised data and facts.

As with all traditional areas of learning, the emphasis on learning mathematics has swung from memorisation of facts and algorithms, to the access and application of information and the understanding of algorithms and of deeper mathematical and philosophical concepts. To facilitate the construction of related knowledge, skills and understanding, educational institutions have (since the late seventies) moved towards a student-centred, co-operative, problem-focused learning environment in which students share past 'experience' as they assist each other to understand and solve relevant problems. In doing so students exercise other important qualities such as co-operation, communication and leadership, which are valued and necessary, within the context of a modern technological society, as they construct their own perspectives, understanding and further experiences.

While this evolution in teaching and learning has been dramatic, it has also been slow. Even the most advanced educational organisations have experienced inertia, as an aging teaching body is called upon to reassess, revitalise and re-implement teaching strategies they have used successfully (if not effectively) for all of their careers. This has been especially evident in the 'West' where an aging teaching body has been required to rewrite curriculum and review teaching strategy with an ever receding educational budget. Despite this, progress has been made. Teaching and learning has adjusted to the new 'approach' along constructivist lines, and 'classroom innovators' are sharing successes and developments with their fellows.

Most Arab countries have made a slow start in implementation of this style of teaching and learning of mathematics. However, with the educational expertise available from 'the West' and other Arab countries, it has been possible to introduce and implement versions of mathematics teaching and learning designed along these lines. Such an approach is highly beneficial for students progressing to higher studies at university, abroad or working in various sectors of business, service, industries and education. In addition to developing mathematical knowledge and skills, and a personalised understanding of 'how and why it works', students will also be versed in those skills necessary for learning and working in the information age. That is, they will possess the ability to think critically, to work co-operatively, to communicate effectively, and will be more self-directed in their learning and the management of their professional and personal lives.

Using a case study approach, this paper describes the evolution (development, implementation, evaluation) along 'constructivist lines' of a mathematics learning-

environment within the foundation year of what could be termed, a selective Arab University.

A brief history

> 'Knowledge is not passively received but actively built up by the cognising subject' (von Glasersfeld, 1990).

This statement, known as the first principle of constructivism, has had enormous implications for teachers of mathematics (amongst many others) and 'the way they do business'. As a philosophical position it fuelled a long-standing debate that continues to burn on many fronts. Epistemologically it questioned long held beliefs about the 'reality' of truth and about the 'viability' of knowledge. Ontologically it cast doubts upon the existence of the 'real and objective world', at the heart of Newtonian real-space. At the very least, it challenged our ability to access such a world.

While these arguments have existed since the time of the sceptics, and will continue to exist as long as humanity reflects upon its own existence, constructivism in questioning these and the very principles by which its critics judge its viability further fanned the flames of philosophical discussion

The critically important work done in the 1980s by von Glasersfeld (1989), which elaborated upon the findings of Piaget established the bona-fides of constructivism as a cognitive position within the theory of learning, and furthermore heralded its evolution into an applied science.

Von Glasersfeld's second principle had even greater implications. 'The function of cognition is adaptive and serves the organisation of the experimental world, not the discovery of ontological reality' (von Glasersfeld, 1989). Supported by the research of Piaget into how cognising beings learn, namely that 'All knowledge is constructed and the instruments of construction include cognitive structures that are either innate (Chomsky, 1968) or are themselves products of developmental construction' (Piaget in Ernest, 1995), von Glasersfeld showed that the process of construction of knowledge and the development of understanding could be explained along similar lines to those explaining Darwin's theories of adaptation and natural selection. Whereas such evidence substantiated the claims made by constructivists for its recognition as a real paradigm, it made constructivism appear even more controversial in the eyes of many critics. However, while the philosophical debate and the emergence and evolution of constructivism as a theory of learning are of notable interest and importance, it is its application as a pedagogical and methodological tool that is of greater relevance to teachers and the greater educational community.

While constructivism in the eyes of many of its adherents and its critics is still under review, what is not under review is its usefulness in explaining how learners learn and its use as a methodological tool and referent for teachers of all disciplines and persuasion. Ernest (1995) writes that 'Acceptance that all knowledge is constructed leads

to methodological constructivism. We have to investigate our subject's perceptions, premises, and methods, even physical and cultural stimuli.'

What constructivism tells us is that all knowledge, understanding and learning processes are constructed in a personalised way. They are dependent upon the prior knowledge, understanding, beliefs and values of the individual. Learning is personal and idiosyncratic. While there are almost as many interpretations[2] of constructivism as there are learners, and much debate as to the importance of the sociocultural influence, constructivists generally agree on the following:

1. All knowledge is constructed. Mathematical knowledge is constructed, at least in part through the process of reflective abstraction.

2. There exist cognitive structures that are activated in the process of construction. These structures account for the construction, that is, they explain the result of cognitive activity in roughly the way a computer program accounts for the output of a computer.

3. Cognitive structures are under continual development. Purposive activity induces transformation of existing structures. The environment presses the organism to adapt.

4. Acknowledgement of constructivism as a cognitive position leads to the adoption of methodological constructivism.

Weak and strong acts of construction

The construction of knowledge can be classified as either weak or strong. These classifications have nothing to do with the truth or the accuracy of the construct. What is of importance here is the method and viability of the construction. A strong act of construction in mathematics could be described as the development of mathematical knowledge and cognitive process by successfully carrying out a mathematical investigation to its socially acceptable conclusion,[3] and making mathematically applicable connections in doing so. A weak act of construction, on the other hand would be learning a formula or a procedure, 'rote' (or erroneously). Here, fewer – if any – legitimate connections are made. The knowledge and/or cognitive process, while not 'stand alone', is not necessarily connected to or constructed from a sound and viable body of prior knowledge.

What this implies is that a learner can perform weak or strong acts of constructivism under almost any conditions. Regardless of the mode of presentation of a learning activity, it is highly likely that some students will construct 'strongly' while others will not. Some students will successfully construct knowledge and processes in a traditional

[2]Paul Ernest (1995) in *Constructivism: The one and the many* lists at least five, from trivial constructivism to social constructionism.

[3]Conforming, of course, to the known rules of mathematics.

lecture style of lesson (despite its inferred limitations) while other students will perform weak acts of construction in lessons where the teacher has gone to great lengths to encourage exploration, participation, discussion, and reflection. The inference here is that we cannot predict how a student will perform in any learning situation unless we have an understanding of their prior knowledge and of their preferred learning style. ‘What is clear is that the emphasis on construction forces us to probe deeply into students’ activity. How firm a grasp do they have on the material? What can they do with it? What misconceptions do they entertain?’ (Noddings, 1984). This leads to wider considerations. In Noddings’ view, ‘we have to investigate our subject’s perceptions, purposes, premises and ways of working things out if we are to understand their behaviour’. For teachers this implies pedagogical constructivism. We need to know what our students are thinking, how they are thinking, and what they can do with the material we present them for ‘processing’. This in turn implies a greater need for analysis of student performance and output.

Thus pedagogical constructivism suggests more sophisticated diagnostic tools – tools that will uncover patterns of thinking, systematic errors, persistent misconceptions, etc. What it does not imply is that constructivism will provide a formula for a new and improved style of teaching and learning. Unless, that is, you consider eclecticism a style. Most teachers attempting to apply constructivist principles utilise some form of differentiated learning, that is, a variety of styles, in an effort to encourage and support all learning styles.

For the classroom teacher, the implications are that there are many paths to the solution of any problem, and that no matter how well planned and how diverse an activity may be, we can never guarantee that all students will possess or develop the skills necessary or even useful in their constructions. However, some necessary skills will recur regularly, and it may be of value to the teacher to consider ‘classroom economies’ in this regard. What this means is that some students may require direct (drills and skills) instruction to bring their basic, requisite skills rapidly up to an acceptable level.

Classroom conditions force us to think about instructional economies. Constructivist teachers need to keep their basic premises in mind, but they should feel free to adapt a wide variety of methods for their own purposes.

Students need to construct, but their constructions need to be guided by mathematical process. Teachers should both model and elicit, but they should model by asking questions, following leads, and conjecturing rather than presenting faultless products. This style of teaching requires considerable mathematical knowledge as well as pedagogical skill. Teachers need to be well prepared and resourced in terms of subject content knowledge and of student awareness.

To achieve the engagement necessary for students to perform powerful constructions it is advisable to increase the amount of time students spend working together, but group work is not a panacea and while some students participate eagerly, others may sit out the session waiting for answers to develop.

As an evolving position, constructivism continues to adapt in response to the per-

turbations (stimuli) produced by its critics and adherents alike. In particular, constructivism has changed to address and explain the data emanating from research into the effects of the sociocultural on learning. 'Learning has an overt cultural dimension, and may even be situation-specific' (Ernest, 1995).

In addressing the questions that have arisen from these perturbations, the constructivist model of learning has moved beyond the personal and idiosyncratic. Constructivists have recognised the relevance and importance of interaction, goal setting and the use of symbolic expression to communicate ideas, and have also accepted the presence and subsequent importance of a social (sociocultural) dimension to learning. Because of the impact of social mediation on the learner, great emphasis is now placed on communication (linguistic and symbolic). As part of this adaptation, constructivist learning theory now places great emphasis on the contribution of language and social interaction, leading to a pedagogy and methodology that is eclectic, and which recognises that all knowledge and understanding is problematic, and that no teaching–learning process is better than another (but each has an enhanced social dimension).

In consideration of the above, teachers need to provide opportunities for students to represent their knowledge in a variety of ways: by writing, drawing, using symbols, and assigning language to what is known. Student thinking needs to be stimulated by providing time to think. Students need time to evaluate what they are learning, make connections, clarify, elaborate, build alternatives and speculate. This is even more so for students learning mathematics in a second language, where all activities double as content and language activities and where the great temptation for teachers and students is to sacrifice 'big picture' understanding for short term identification.

Case study: Foundation Mathematics

The Petroleum Institute (PI) in Abu Dhabi is a privately owned[4] tertiary institution geared to producing engineers[5] for the oil industry. The majority of students are Emirati nationals, although in recent years the PI has accepted the expatriate children of long-term employees of ADNOC, provided their marks are acceptable. Entry to the PI is based on students achieving outstanding results in their final (national) secondary school examinations, including a TOEFL[6] score of 400+ and upon successfully passing an interview with the ADNOC/PI admissions panel.

Successful candidates are tested again upon entry to the PI, to determine their level of English, and their ability levels in Mathematics, Science and Information Technology. If the results of these tests are exceptional, students may be permitted to go directly into first year and start work on their Engineering degrees. This is a very rare occurrence. Most students spend their initial year at the PI in the Foundation Program,

[4]Abu Dhabi National Oil Company (ADNOC) and its industry partners: Shell, BP, Total, ELF FINA and JODCO.

[5]Petroleum, electrical, chemical, mechanical, and petroleum geosciences.

[6]Test Of English as a Foreign Language.

revising Mathematics, Science, IT and English. In all cases the language of instruction is English. For students with TOEFL scores below 500, the initial semester is one of intensive 'English language' study, followed by two semesters of Mathematics, Science, IT and English.

The Foundation Mathematics course at the PI is pre-calculus and is designed to meet the outcomes set down by the Core Mathematics programme. The goal of the course is to review and revise *in an English language medium*; the mathematics is meant to be mathematics that the students have previously seen in secondary school. More importantly, the programme's aim is to introduce students to the concepts, processes and technology of mathematical modelling and problem-solving; something that many students have not encountered while studying mathematics in secondary school.

Because the very process of Engineering involves the collaborative design of solutions to problems through the application of mathematical modelling, (issues at the very heart of constructivist philosophy and methodology, see Appendix A), the Foundation Mathematics Program has (in the interest of continuous improvement) been evaluating and refining its teaching and learning methodology with the aim of providing an effective constructivist learning environment.

To facilitate the above, the programme has adopted a multi-faceted strategy which includes:

1. Testing each incoming student's baseline English–Mathematics vocabulary in four areas (Physical – Algorithmic – Logical – Symbolic);

2. Evaluating each incoming student's problem-solving 'repertoire' and preferred strategy – if any – for solving simple and complex problems (SPAIN[7]);

3. Locating student misconceptions and 'blind spots';

4. Identifying and classifying students as either *Targeted*, *General*, or *Gifted* (based on the results of baseline testing) and developing teaching–learning strategies for each group;

5. Tracking the progress of targeted students (such as their development of problem-solving strategies and growth of understanding of basic concepts) through analysis of their responses to nominated questions within assessment tasks and classroom activities;

6. Adopting a differentiated teaching strategy. While we are still bound by the constraints of too much content and too little time, a concerted effort has been made to select questioning techniques and relevant problem-solving activities that will facilitate collaboration, discussion, strategic thinking, negotiation, and shared meanings;

[7]Successful – Pictorial – Algorithmic – 'Illgebraic' – Numeric. See later in the text for a description of SPAIN.

7. Delivering mathematical content and ideas using multiple representations of information, including visualisation, which is sensitive to the background of our students.[8]

1. The baseline test

This consists of four sections of ten questions each. The sections are Physical Vocabulary, Algorithmic Vocabulary, Logical (or Positional) Vocabulary and Symbolic Vocabulary. In the Physical and Algorithmic sections, students are required to match physical shapes, objects or common algorithms to their English language descriptors. In the Logical/Positional section they are required to position or locate elements of sets according to a simple instruction. In the Algebraic section students are required to manipulate symbols as directed by each question.

The expected outcome for the baseline test is that all students will score 100%, because in these questions all terms, objects, concepts etc., are assumed eminently doable and totally familiar to students at this level of mathematics.[9] Surprisingly, even with our students' strong backgrounds in Mathematics and English, this is far from the case, prompting us to re-evaluate our delivery methods and methods of assessment (see Figure 1).

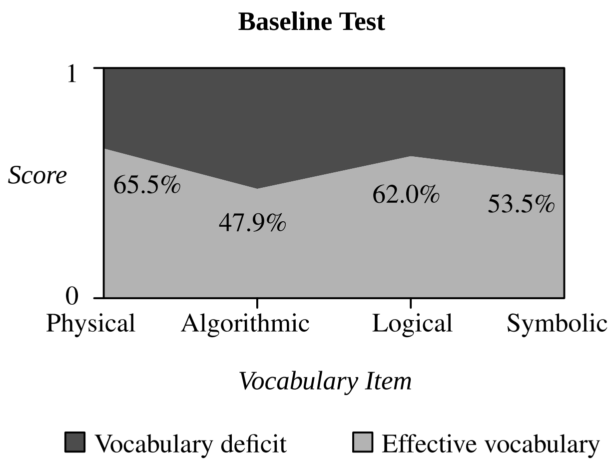


Figure 1: Baseline test results.

[8] It appears that many students come from a rote-learning environment in which conceptual understanding has been 'traded off' against the short term benefit of vocabulary development or algorithmic/symbolic manipulation.

[9] All objects, ideas, symbols, etc., are taken from teacher notes, anecdotes, secondary school syllabi, introductory tests, etc., and are recognised by our teachers as assumed and necessary knowledge.

Teacher	Count	S	P	A	I	N	SPAIN	%
A	32	17	25	23	16	17	9	28.1
B	19	10	14	11	9	12	7	36.8
C	48	20	21	20	21	17	9	18.8
D	11	6	8	8	7	3	2	18.2
E	19	15	17	15	16	10	4	21.1
Total	129	68	85	77	69	59	31	
Percentage	100%	53%	66%	60%	53%	46%	24%	

Table 1: Problem-solving analysis – Ships problem (See Appendix F)

2. SPAIN (Successful – Pictorial – Algorithmic – 'Illgebraic' – Numeric)

This is used to determine a student's problem-solving versatility and preference. Although not a conclusive method, SPAIN allows us to identify students with limited problem-solving strategies and also students who are gifted-and-talented in this respect. In this procedure students are guided through what is initially a relatively simple problem that increases in complexity. To solve the problem students can apply some or many of Polyas' methods.

Once again, results were surprising (see Table 1). Only 24% of all students completed the problem successfully and approximately one third of our students did not use a diagram in a problem which by its very nature (compass directions) suggested a drawing was necessary.

SPAIN results are combined with the baseline scores, assisting teachers to identify those students who are at risk and those who are a potential resource as mentor or peer group leader. At risk (targeted) students are then tracked further to monitor the success of any remedial action taken by the teachers.

3. Locating student misconceptions and blind spots

One advantage of 'tracking' targeted students has been to identify misconceptions or knowledge-gaps in basic skills areas. One concept tested was that of the product of gradients of two perpendicular straight lines. This product is always negative one ($m_1 \times m_2 = -1$). Most students were able to recognise this and successfully complete the problems given, however, a sizeable number were unable to perform the same calculation when told that the lines intersected (crossed at 90°).

Analysis of similar questions (see Table 2) involving vertical and horizontal lines and their gradients, and the relationship between parallel lines, indicated that a number of students did in fact have vocabulary problems in discriminating between parallel and perpendicular lines, and some recognised perpendicularity as applicable only to hori-

Sample size	Vocab. horizontal	Vocab. vertical	Vocab. perpendicular	No Picture parallel
32	9	5	9	1
16	3	5	5	7
35	10	9	15	1
11	6	3	3	1
94	28	22	32	10

Table 2: Tracking misconceptions – Perpendicularity

zontal and vertical lines. However, a majority of those unable to perform the calculation did so because they did not connect the term 'perpendicular' with two lines intersecting at $90°$. In short, it appeared that the students had learnt the algorithm $(m_1 \times m_2 = -1)$ rote and connected it only to the term 'perpendicular'. When interviewed, some students could indeed link perpendicularity with lines intersecting at $90°$, yet were still unable to connect this back to the original algorithm without explanation. This would possibly indicate that some students learn mathematics by tagging 'algorithmic' and physical 'concepts' with linguistic identifiers, but do not complete the connection between the two related 'concepts'.

This may be a result of the way the students are learning (or have learnt) to read and speak English and would indicate incomplete mastery of the language by the student at the time of completing secondary school, or it may be due to cognitive limitations of the student involved in general.

Another factor could be student work ethic and expectations, in that students often copy the homework of others, taking down what they consider the salient points rather than seeking complete understanding or a practical insight achieved by doing the problems themselves.

In the case of the Mathematics teachers, a certain degree of pragmatism is involved whereby targeted students are shown the 'whole picture' wherever possible.[10] However, recognition of these misconceptions has made teachers aware of the importance of wider issues on student success and upon the effectiveness of their own 'delivery', and teachers have taken steps to address these issues inside and outside their classrooms.

4. Identifying and classifying students

Data taken from the baseline and SPAIN tests allow teachers to identify students as *Mentors*, *Peers* or *Stars*.[11]

[10]Time constraints and classroom economies play a big part in how successfully this remediation can be done. Often it is left to the individual teacher to attempt during office hours or through peer mentors.

[11]Stars are students at risk.

Mentors are those students whose results are very strong and whose problem-solving skills are highly evident and in use. These students are encouraged to be group leaders within problem-solving and homework activities. Where it is applicable they are given extension or enrichment activities, which may also be analysed to determine how they approach problem-solving.

Peers are those students whose results are acceptable and whose problem-solving skills are evident. Most of our students fall into this category. These students are tracked through their responses to selected questions within regular testing and assessment activities.

Stars are those students who are at risk of failing the course. Their results are poor[12] and/or their problem-solving skills are 'limited'. About 20% of our students fall into this category (for one reason or another). These students are tracked regularly including homework responses and classroom activities. To assist teachers with remediation, many are teamed with a mentor student and invited to work regularly one-on-one with teachers during 'office hours'. Where teachers consider the problem may be English language related, students are (sometimes) directed to the English faculty for extra help.[13]

5. Tracking progress of targeted students

As mentioned above, students are tracked through their responses to general and specific questions in assessment and classroom activities. Different students may be tracked differently and for different reasons, although each assessment task contains specified questions[14] designed to track all students and to locate problems and progress.

6. Differentiated teaching and learning

Having observed the results of the baseline and SPAIN testing, teachers are aware of the wide differences in student mathematical ability, mathematical vocabulary and problem-solving capability. Consequently, teachers have developed a differentiated approach to teaching these courses. While student expectations are predominantly that the teacher lectures, demonstrates by way of example, then monitors students as they solve 'example clones', teachers have diversified their approach. Often students are presented with quizzes or stimulus problems, which connect new with old content, or engage student thinking for the upcoming activities. Students may be challenged individually or in groups, may solve similar or different problems from their peers, or may be required to research their own lesson introductions.

[12]Below 60% for Pre-calculus 1 students and below 70% for Pre-calculus 2.

[13]The PI English programme runs an Intensive English Program for incoming students with TOEFL scores between 400 and 500. While this course helps immensely, there is still need for early intervention for development of 'content' vocabulary and in mathematical thinking.

[14]SPAIN

In general, different teachers adopt and report back on different approaches, but in most cases their activities are predetermined and designed to ensure that students (over a given period) will have the opportunity to represent their knowledge in a variety of ways, by writing, drawing, using symbols, and assigning language.

7. Delivering mathematical content and ideas using multiple representations

In an ESL environment it is essential for teachers to convey ideas in a variety of ways, enabling students to get a clear and concise understanding of what is being taught. Teaching using visualisation is a major part of such a process. Such an approach involves the teacher providing pictorial information in support of linguistic or symbolic description. It may take the form of a simple sketch or a graphical identifier such as an arrow (e.g. increasing $\nearrow$ or increasing) or it may take the form of a derivation which is demonstrated to the group in order to connect the work they are doing with some other important mathematical idea. A typical example of this is the proof of the formula $m_1 \times m_2 = -1$ for two lines which are perpendicular to one another. Students who have seen this derivation have fewer problems in connecting the formula, its linguistic identifier (word) and its graphic (two lines intersecting at ninety degrees).

Workshop: Exercises and assessment activities

Materials are designed for the three ability levels. Ideally the Stars materials would best be used in an Intensive English Program to develop students content vocabulary and mathematical thinking skills. The Peers materials are designed for normal mathematics classes – all students will come across these. The Mentors materials are enrichment materials. Some are designed as course extension-work, others exclusively as critical thinking exercises.

In all cases the exercises and their application are designed to adhere to the principles and protocols evident in appendices A, B and C. The activities are numerous, with some samples provided in appendices D, E and F.

Conclusion

The great strength of constructivism lies in its application as a pedagogical and methodological referent. Acceptance of constructivist principles means admitting that there is no preferred learning style or teaching process. It encourages us, as teachers, to look more closely at what our students know already and how they go about learning what they know. It encourages us to adopt an eclectic approach to our teaching in which we consider that our students are not just making connections and developing a base of content knowledge, but developing cognitive and meta-cognitive structures and strategies as well. More importantly, these constructions are a social activity. While our learner is developing these structures, he or she is doing so in a social context. This

means we should be developing teaching/learning strategies with our classrooms-as-cultural 'environments' in mind.

Appendices

A. Implications of constructivist principles

These have been adapted from Ernest (1995).
Pedagogical

- Sensitivity toward and attentiveness to the learner's previous constructions (knowledge, understanding, appreciation, methods).
- Diagnostic teaching attempting to remedy learner errors and misconceptions; perturbation and cognitive conflict techniques as part of this.
- Attention to meta-cognition and strategic self-regulation by learners.
- Use of multiple representations of mathematical concepts.
- Awareness of importance of goals for the learner, and the dichotomy of teacher-learner goals, and
- Awareness of the importance of social contexts, such as the difference between folk or street mathematics (and an attempt to exploit the former for the latter).

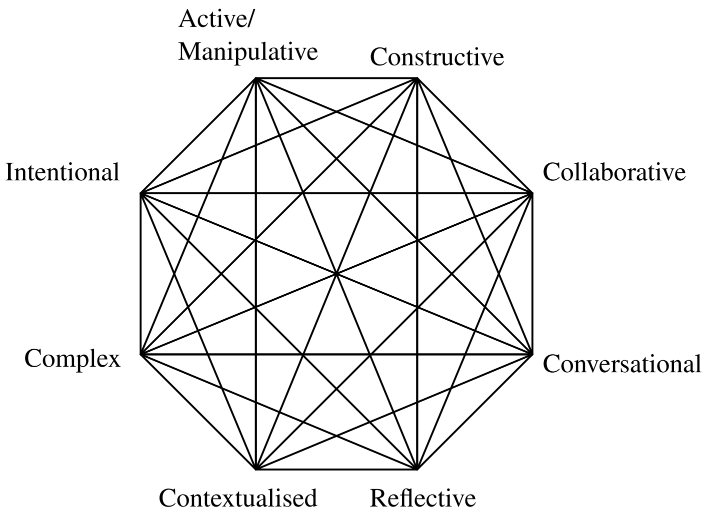
Philosophical

- Knowledge as a whole, is problematised, not just the learner's subjective knowledge, including mathematical knowledge and logic.
- Methodological approaches are required to be much more circumspect and reflexive, because there is no 'royal road' to truth or near-truth.
- The focus of concern is not just the learner's cognitions, but the learner's cognitions, beliefs, and conceptions of knowledge.
- Although we can tentatively come to know the knowledge of others by interpreting their language and actions through our own conceptual constructs (filters), the others have realities that are independent of our own.
- An awareness of the social construction of knowledge suggests a pedagogical emphasis on discussion, collaboration, negotiation and shared meanings.

B. Constructivist learning environments

These are taken from Johannsen (1991), University of Missouri, Designing Constructivist Learning Environments.[15]

The following characteristics of meaningful learning provide guidelines for designing constructivist learning environments.



Learning environments should display the characteristics above.

Learning activities should be

active	constructive
collaborative	intentional
complex	contextual
conversational	reflective

C. Problem-solving categories

After Schoenfeld (1995)
Resources

- Knowledge about the problem domain

[15] Available at: `www.coe.missouri.edu/%7Ejonassen/courses/CLE/`. Here you can find a clear description of each of the definitions used.

- Facts, data, definitions
- Ability to execute algorithmic procedures
- Ability to carry out routine procedures
- Knowledge of rules of discourse

Heuristics

- Use an analogy
- Draw a figure or graph
- Try some special cases
- Identify sub goals
- Work backwards
- Derive something from the data
- Identify a related problem
- Make use of symmetry

Control

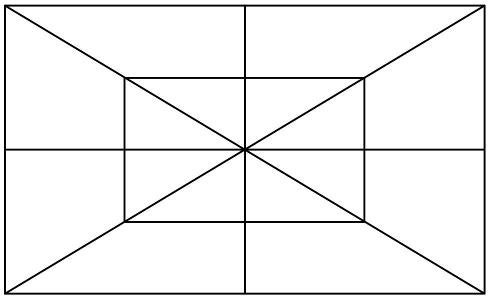
- Identify key features of a problem
- Consider all relevant methods before starting
- Monitor solution process
- Assess validity of intermediate solutions
- Be prepared to switch method
- Avoid complicated analysis where possible

Belief

- Unquestioned intuitive knowledge
- Use of a particular heuristic (always)
- Believe incorrect solution is correct
- Incorrect decision that something is obvious
- I can never see such problems

- That sort of problem is always solved this way
- All these problems can be done simply
- Problems are always harder than they seem
- Material is of no particular use

D. Sample 1: Intensive English Program – Mathematical vocabulary



In the picture above, locate (by shading) each of the objects listed below.

Each object scores 2 marks, unless it shares a line with another object, then it is only 1 mark. Maximise your score.

(a) horizontal line

(b) vertical line

(c) two parallel lines

(d) two perpendicular lines

(e) a right triangle

(f) an isosceles triangle

(g) a rectangle

(h) a trapezium

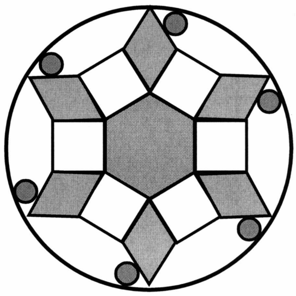
(i) an acute angle

(j) an obtuse angle

(k) a right angle

E. Sample 2: Mathematics for Arts Program – Mathematical reasoning

ISLAMIC ART (As seen in Carrefours in Al Ain, UAE)



In this design.

Q1 How many

(a) squares............

(b) diamonds............

(c) hexagons............

(d) circles............

(e) octagons............

Q2 Give the *ratio* of

(a) squares to circles............

(b) diamonds to hexagons............

(c) diamonds to squares............

Q3 What fraction of shapes are

(a) circles............

(b) diamonds............

Q4 Divide the hexagon into 6 congruent triangles.

Q5 The internal angle of the

(a) triangles = ...° (degrees)

(b) squares = ...°

(c) hexagon = ...°

(d) diamonds = ...°

Q6 Does this design have symmetry? Answer with either Yes or No.

(a) How many *lines* of symmetry?...........

(b) What is the *order of rotational* symmetry?...........

Q7 The perimeter of the *design* (*without* the circles) is 36 metres.

(a) What is the length of the square?...........

(b) What is the *perimeter* of the hexagon?...........

Q8 On the *drawing* the perimeter of the *design* is 9 cm.

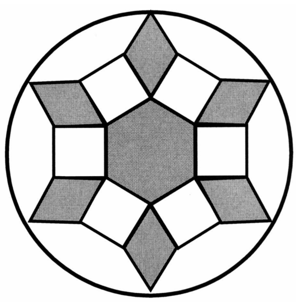
(a) What is the *scale*?...........

(b) What is the *perimeter* of the hexagon?...........

Q9 On the floor of Carrefours, the *perimeter* of the circle is 17.5 metres.

Use proportion to find the perimeter on the drawing ?

Q10 The true design (at Carrefours), has NO small circles. It has 12 diamonds (NOT 6). The diamonds and squares make 6 cubes.



Draw the lines that make this design the true design

F. Ships problem (SPAIN)

Two ships leave Jebel Ali port at exactly 6.00 am. Ship A sails east at 30 kilometres per hour and ship B sails north at 40 kilometres per hour.

(i) Calculate the distance between the two ships after 3 hours.

(ii) At what time will the distance between the two ships be exactly 100 kilometres?

References

ERNEST P. (1995). Constructivism: The one and the many, in L. P. Steffe and J. Gale (Eds), *Constructivism in education* (pp. 459–486). Erlbaum: Hillsdale, New Jersey.

JONASSEN, D.H. (1991). Evaluating constructivist learning, *Educational Technology*, **31**(9), 28–33.

NODDINGS N. (1984). *Caring: A feminine approach to ethics and moral education*. University of California Press: Berkeley, CA.

SCHOENFELD, A. (1995). *Mathematical problem solving*. Academic Press: Orlando.

VON GLASERSFELD, E. (1990). An exposition of constructivism: Why some like it radical, in R. B. Davis, C. A. Maher and N. Noddings (Eds), *Constructivism views on teaching and learning mathematics* (pp. 19–29). National Council of Teachers of Mathematics: Reston, VA.

VON GLASERSFELD, E. (1995). A constructivist approach to teaching, in L. P. Steffe and J. Gale (Eds), *Constructivism in education* (pp. 3–16). Erlbaum: Hillsdale, New Jersey.

Meeting the challenges of mathematics: Dyscalculia and math anxiety

Cristina Lai

Mathematics Department, Sheikh Zayed Academy for Girls, Abu Dhabi, United Arab Emirates

Introduction

For the average student, mathematics is often viewed as a subject that is already difficult. The challenges of mathematics become even greater for those students who have learning disabilities. Dyscalculia is a learning disability in mathematics which can be diagnosed from an age as young as pre-school children. If the syndrome of dyscalculia is not recognised, then it could lead to perpetual failure in mathematics, which could have wider consequences in overall academic achievement, personal development, and esteem. Dyscalculia often leads to math anxiety. Math anxiety has been defined as feelings of tension and anxiety that interfere with the manipulation of numbers and the solving of mathematical problems, both in the wider context of ordinary life as well as in academic situations. This can cause the individual to have feelings of panic and paranoia, and may lead to a loss of self-confidence. In this paper, we will look at dyscalculia and math anxiety by identifying symptoms and offering strategies for coping with or overcoming these debilitating deficits.

What is a learning disability?

Learning disabilities are neurologically-based processing problems. They could affect how the information gets into the brain (input), how the information is made sense of or understood (organisation), how it is stored and later retrieved (memory), or how the information gets put back out (output). These processing problems can interfere with learning basic skills such as reading, writing, or mathematics. They can also interfere with higher order skills such as organisation and abstract reasoning.

Learning disabilities should not be confused with learning problems which are primarily the result of motor handicaps, mental retardation, emotional disturbance, environmental or economic disadvantages. Generally, people with learning disabilities are

of average or above average intelligence. There often appears to be a gap between the individual's potential and actual achievement. This is why learning disabilities are often referred to as 'hidden disabilities'. A learning disability cannot be cured or fixed; it is a lifelong challenge. 'Learning disabilities' is an umbrella term covering other more specific learning disabilities, such as dyslexia (a language and reading disability), dysgraphia (a writing disorder resulting in illegibility) and dyscalculia (problems with arithmetic and mathematical concepts). The learning disability related to mathematics known as dyscalculia will be considered in this paper.

Case study

Anita is a student who has excellent grades in all her subjects. Mathematics however is really hard for her and she only manages to get 65% with extreme effort, which is what she has always done in mathematics. She is frustrated by this seemingly insurmountable subject but she cannot identify and define the obstacles to her achievement. Because her reading comprehension is excellent, she thinks that by re-reading her mathematics text she will gain sufficient clarification in the material that she failed to understand in class. But she does not.

She begins to seek help from others. Encounters with peers, tutors or teachers do not improve her understanding. She begins to feel extreme frustration by these sessions, particularly as she is expending precious time without profit. She falls farther and farther behind and the prospects for catching up become bleaker.

The student becomes anxious. Before the gate of her goals stands mathematics. It threatens her entry into a world of high grade point averages, academic honours and university scholarships. It threatens to slam the door shut on her occupational dreams.

But she refuses to give up. After all, everything else has been so easy! Surely there is a trick to be learnt here, a study strategy. She knows she is very intelligent and she refuses to be beaten by one subject. She is determined not to fall behind, but to do whatever it takes to be on top of the material.

Unfortunately, despite her lifelong difficulty in learning mathematical concepts, no one has ever taken her aside and tested her for a specific learning disability in mathematics. Because she is so brilliant in everything else, her mathematical difficulty is thought to be a transient fluke. Surely this intelligent girl will grow out of it. And it is believed that, even if she does not, her far reaching academic talents will prevail, cushioning her from any life-long effects of mathematics failure.

Anita is a typical example of someone experiencing dyscalculia. If a teacher had known of the learning disability dyscalculia, then the contradictions between Anita's performance in mathematics compared with her other subjects would have sounded the warning bells and the symptoms could have begun to be recognised. What then are the symptoms?

What is dyscalculia?

Dyscalculia is a learning disability that affects mathematical calculations involving visual processing and sequencing. Signs and symptoms of dyscalculia include:

- Spatial problems and difficulty aligning numbers into proper columns.
- Trouble with sequence, including left/right orientation. Students will read numbers out of sequence and sometimes do operations backwards.
- Difficulty understanding and doing word problems.
- Inconsistent results in addition, subtraction, multiplication and division. Poor mental mathematics ability. Being poor with money and credit and being unable to do financial planning or budgeting.
- The inability to grasp and remember mathematical concepts, rules, formulae, and sequence (order of operations). Poor long-term memory. Students understand material as they are being shown it, but when they must retrieve the information, they become confused and are unable to do so. They may be able to perform mathematical operations one day, but draw a blank the next. They may be able to do book work but fail all tests and examinations.
- Lacking 'big picture/whole picture' thinking.
- Difficulty keeping score during games, loses track of whose turn it is during games, etc.
- It is common with students with dyscalculia to have normal or accelerated language acquisition: verbal, reading, writing, and good visual memory for the printed word. They are usually good in creative arts.

Some *strategies* to help a student suffering from dyscalculia include:

- Allow use of fingers.
- Use diagrams and draw mathematical concepts.
- Provide peer assistance.
- Suggest use of graph paper.
- Suggest use of coloured pencils to differentiate problems.
- Work with manipulatives.
- Suggest drawing of a picture for word problems.
- Recommend use of mnemonic devices to learn steps of a mathematical concept.

- Use rhythm and music to teach mathematical facts as steps to a beat.
- Schedule computer time for the student for drill and practice.

Of course, not all of us in a busy classroom with a busy teaching schedule can find the time to devote to these particular students. These students benefit from the teacher's ability to recognise them as having a learning difficulty and not to classify them immediately as being lazy or unwilling. A student with dyscalculia qualifies to have attention from a special education department, as well as special allowances by the mathematics teacher to cope with this genuine difficulty. In the case of schools in Ontario, Canada, for example, some of the accommodations made include:

- Time and a half for evaluations; be they quizzes, tests or examinations.
- A formula sheet.
- A calculator.
- Different method of assessment; a scribe, an interpreter for the questions, verbal testing, etc.
- Some assistance in reminding, 'jogging' the memory, in problems involving sequencing, step-by-step solutions.

Of course, many teachers are unwilling to give the student so much assistance without being certain that the student is deserving of it. If a teacher suspects that the student may suffer from dyscalculia by displaying some of the symptoms above, then the student should be referred to authorities in special education for testing. It is only when the student has formally been tested, identified and labelled as having a learning disability that the student qualifies to receive assistance. If there is no institutional testing mechanism in place, then it is up to the teacher's discretion to offer the assistance or not.

In the case study of Anita above, we saw that she was immensely frustrated by her inability to overcome the difficulties that she experiences in mathematics. All this, in turn, leads to math anxiety.

What is math anxiety?

Math anxiety has been defined as feelings of tension and nervousness that interfere with the manipulation of numbers and the solving of mathematical problems in a wide variety of ordinary life and academic situations. Math anxiety is a learnt emotional response to one or more of the following:

- Participating in a mathematics class.
- Listening to a lecture.

- Working through problems.
- Discussing mathematics.

Where does math anxiety come from?

Math anxiety usually comes from negative experiences in working with teachers, tutors, classmates, parents or siblings. Other times the anxiety comes from stress or a personal problem which was going on at the same time s/he was learning a particular concept. In this case, s/he associates mathematics with whatever was going on at that time.

What are the *symptoms* of math anxiety?

- Panic – students have a feeling of helplessness. They feel that a brick wall has come down and they will never do better and have reached their limit in mathematics.
- Paranoia – students have a feeling that everyone knows the answer except them. They feel they have been faking mathematics for years and everyone knows it.
- Passive – they have an attitude that either they have a mathematical mind or they do not. There is nothing they can do to become better in mathematics. They sit back and do not take action.
- Lack of confidence – they do not trust their intuition. They rely on memorising rules or examples instead of trying to understanding the concepts.

All these are self-defeating attitudes which form the coping mechanism for the student. By using the word *coping* here, I do not mean they are coping with the subject mathematics; it is how they cope with how they feel about mathematics.

If we see that a student struggles with mathematics and experiences anxiety, a number of strategies can be suggested. First we can offer plenty of assurance that mathematics is not an impossible subject and help the student to admit to the anxiety and to look within to find the source of the anxiety, asking her/him to think back to the first time when difficulty with mathematics was experienced.

FOR STUDENTS – How to reduce math anxiety

- Overcome negative self-talk.
- Realise that you are not alone! Many people dislike or feel anxious about mathematics.
- Ask questions.
- Think of mathematics as a foreign language – it must be practised!

- Get help on the same day that you do not understand the material; do not procrastinate.
- Study mathematics according to your ‘learning style’ and in the environment that works best for you.
- Avoid teachers/peers/family who are not helpful or supportive.
- Do mathematics in a way that you are comfortable with. Remember there is more than one way to do a mathematical problem.
- Take breaks. Do not work for hours on end. It is good to take a break every 50 minutes or so.

FOR TEACHERS – How to help with reducing math anxiety for students
Research confirms that pressure of timed tests and risk of public embarrassment have long been recognised as sources of tension among students. These are a regular part of the traditional mathematics classroom and they cause a great deal of anxiety. Therefore, teaching methods must be re-examined.

- There should be more emphasis on teaching methods that include less teacher talk and more student-directed classes and discussion.
- Co-operative groups provide students with a chance to exchange ideas, to ask questions freely, to explain to one another, to clarify ideas and to express feelings about their learning.
- Lessons must be presented in a variety of ways to encompass the fact that each individual has a different way of learning. For example, different ways to teach a new concept can be through analogies, visual aids, hands-on activities or through the use of technology.
- Mathematics needs to be relevant to the learner’s everyday life. To learn mathematics, students must be engaged in exploring, conjecturing, and thinking, rather than engaged in rote learning of rules and procedures.

Conclusion

The needs of society today, as ever, require knowledge of mathematics. In order to satisfy this need, mathematics teaching and learning must be tackled in a positive light for all. For students suffering dyscalculia or math anxiety, it is deemed obligatory of us, the teachers, to be alerted to their symptoms and to assist them in maximising their potential by reaching out to them in a compassionate, sensitive and helpful way. As educators, we must expand our horizons by extending our teaching in directions previously unexplored. Only by doing so can we help to foster understanding and possibly love for this difficult yet fascinating subject, mathematics.

References

CARNINE, D., DIXON, R. AND SILBERT, J. (1998). Effective strategies for teaching mathematics, in E. Kameenui and D. Carnine (Eds), *Effective teaching that accommodates diverse learners* (pp. 93–112). Merrill: Columbus, OH.

CARNINE, D., JONES, E. AND DIXON, R. (1994). Mathematics: Educational tools for diverse learners, *School Psychology Review*, **23**, 406–427.

CASE, L., HARRIS, H. AND GRAHAM, S. (1992). Improving the mathematical problem solving skills of students with learning disabilities: Self regulated strategy development, *Journal of Special Education*, **26**, 1–19.

PHILLIPS, M. (1999). *Math attack: How to reduce math anxiety in the classroom, at work and in everyday personal use*. Allyn and Bacon: New York.

SPIKELL, M. (1993). *Teaching mathematics with manipulatives: A resources of activities for the K–12 teacher*. Allyn and Bacon: New York.

TOBIAS, S. (1993). *Overcoming math anxiety*. Norton and Company: New York.

Analysis of problem-solving in mathematics teaching and learning

B. Yushau[1] and D. C. J. Wessels[2]

[1]*Department of Mathematical Sciences, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia*
[2]*Department of Further Teacher Education, University of South Africa, Pretoria, South Africa*

Recently, the concern of mathematics educators has shifted from teachers teaching to students learning. As a result, a student-centred approach to the teaching and learning of mathematics has gained considerable attention in recent years. In most cases the term used for such an approach is one of problem-solving. However, the term problem-solving has become a slogan encompassing different things to different people. In this paper we intend to give a clear delineation between traditional and modern approaches to problem-solving using some key elements in the teaching–learning situation. This includes the philosophy, aims and objectives, teaching and learning strategies, the selection of content, media selection and use, and the evaluation process.

Introduction

Humans are known for their unique ability to solve problems. A pertinent example is the engagement and preoccupation of mathematicians in seeking solutions to particular problems. Mathematics as a subject has long been among the core courses found at all levels within formal educational systems. Traditionally, it is assumed that mathematics by its nature can provide certain skills of solving problems extendible to other domains. However, experience has shown that this rarely seems to be the case. The essence of the matter is that it is fairly difficult to promote the idea of thinking mathematically, and it is only when it occurs that the transfer of problem-solving strategies to other terrains of life will take place. This has prompted debate and research into more effective teaching approaches with a potential to help the learner to transfer acquired knowledge and skills in school to real life problems. Among the numerous approaches advocated, the most

popular one is problem-solving (Kwari and Wessels, 2003). Some of the advantages that give problem-solving an upper hand over other completing approaches include (see Bell, 1978, p. 119):

1. The learning objectives that are met by solving problems and learning general problem-solving procedures are of significant importance to society.

2. Principles that are learnt and applied in problem-solving sessions are more likely to be transferred to other problem-solving situations than principles that have not been applied in solving problems.

3. Mathematics problem-solving can increase students' analytical power and creativity, and can aid them in applying these powers in diverse situations.

4. Solving problems helps students deepen their understanding of mathematical facts, skills, concepts, and principles by illustrating the applications of mathematical objects.

5. Problem-solving is a fascinating activity for most students, therefore, solving problems in mathematics courses can improve motivation and makes mathematics more interesting.

6. Most importantly, problem-solving is student-centred. The student is not only actively involved but is the main actor of the show while the teacher acts as a facilitator. This makes mathematics a truly non-spectator sport!

However, as rightly noted by Stanic and Kilpatrick (1988), with this focus on problem-solving has come confusion. 'The term problem-solving has become a slogan encompassing different views of what education is, of what schooling is, of what mathematics is, and of why we should teach mathematics in general and problem-solving in particular' (p. 1). Amidst this confusion, this paper intends to show how problem-solving in the modern sense differs from the traditional approach to problem-solving, using some key elements of the teaching and learning process.

Problem-solving

In trying to make sense of exactly what problem-solving is all about, perhaps the most natural question that one should firstly ask is 'What is a problem?' However, looking critically into the meaning of the term 'problem' (literally or technically), one easily realises that the term 'problem' is local rather than generic. What is deemed a problem to one person may not be seen as a problem to another. Bell (1978) outlined conditions that must be fulfilled for a problem to be a problem. These are:

1. A person must become aware of a situation in order for it to be a problem for him or her.

2. He or she must recognise the fact that the situation requires some action.
3. The person must either need to or want to act upon the situation and must actually take some action.
4. The resolution of the situation must not be immediately obvious to the person who acts upon it.
5. The person has not previously solved that particular problem, even though many other people may have solved the problem previously.

It has been observed that, by implication, most of the exercises found at the end sections of most mathematics textbooks are technically knocked out of this characterisation. This is due to the fact that many of these exercises are designed for routine drill and practice. However, whether or not an exercise in mathematics is a problem, depends upon how the student regards it and how he or she goes about solving it (Bell, 1978).

As noted earlier, problem-solving means different things to different people. As a matter of fact, three mutually exclusive usages of the term 'problem-solving' can be deciphered from Ernest (1991). Firstly, the term is used as 'the object or focus of inquiry', secondly as a 'process of inquiry', and thirdly as a 'pedagogical approach to mathematics' (pp. 284–286). Hence, 'great confusion arises when the same term refers to a multitude of some time contradictory and typically underspecified behaviour' (Schoenfeld, 1992, p. 364). Yet, as Jacobson (1966) noted 'all would agree that it is the active participation in mathematical activity that is being sought' (p. 101). Since a 'problem' must involve a student and the student must search for the answer, a dividing line is then the degree to which the student partakes in solving the problem.

As a result of this multifarious and conflicting meaning of problem-solving, we shall now advance our argument in two divergent directions, which we resort to calling the 'traditional approach' and the 'modern approach' to problem-solving. This can be understood from the two major continua in which problem-solving has been used: from 'working rote exercises' to 'doing mathematics professionally' (Schoenfeld, 1992, p. 334). By a traditional approach we mean approaches that consider problem-solving as merely solving routine problems. These are problems that can be solved by straightforward mechanical application of rules and the student has no difficulty in finding out which rule to apply (Polya, 1966; Schoenfeld, 1992). While by a modern approach we mean those who consider problem-solving as solving non-routine problems that are usually challenging, perplexing and require some degree of creativity which is typical of that found among professional mathematicians.

Element	**Traditional Approach**	**Modern Approach**
Philosophy of mathematics	The philosophy of mathematics espoused by the traditional problem-solving approach is absolutist (see Ernest, 1991). It considers mathematics as objective, absolute, and certain. It is an incorrigible body of knowledge.	The philosophy of mathematics of modern problem-solving is largely Fallibilist (see Ernest, 1991). It considers mathematics as a human invention, hence, fallible, corrigible, and eternally open to revision and correction.
Aims and objectives	Problem-solving here aims at justifying teaching mathematics, providing specific motivation for subject topics, for recreation, as a means of developing new skills, and as practice (see Schoenfeld, 1992).	Not as a means to an ends, rather part of the process aims at giving students deeper understanding of the basic mathematical concepts and to stimulate them to do creative and independent thinking with these concepts.
Teacher	The teacher is the alpha and the omega, s/he decides what the student should know.	Here, the teacher is like a mentor with a carefully skilled plan which will facilitate a genuine mathematical learning process.
Students	An empty vessel waiting to be filled with facts and knowledge.	Peripheral participant in mathematical activities. Central-stage participant in learning mathematics through a carefully selected series of activities where mathematics is learnt through solving problems.

Content	An accumulation of facts, rules and skills available in the syllabi, and curricular material arranged in a hierarchical order.	A dynamic, continually-expanding field of human creation and invention, a cultural product, and a process of enquiry.
Teaching	Lesson is presented in an expository manner: give a definition or theorem and follow it up with some examples or counter-examples to illustrate what the definition or theorem is all about.	The focus here is on the process. Students are guided inductively to 'discover' things on their own with teacher facilitation. Therefore, students are taught how to fish rather than given a cooked fish and told to swallow.
Learning	Learning mathematics is defined as mastering, in some coherent order, the set of facts and procedures that comprises the body of mathematics.	Learning is an active participation in the invention or creation of mathematics based on human activity and enquiry. To know is to be able to do.
Instructional media	Teaching is done in an expository manner, so chalkboard, pencil and paper, and textbooks are the main material the teacher and the student use in solving problems.	In addition to pencil and paper, students require more aids such as calculator, computers, etc., to explore real life problems and uncover mathematical patterns. Learning does not take place only in the classroom.

Evaluation	The assessment is to verify how far the student has mastered the skills, procedures and concepts. Hence, the assessment is largely formative in nature.	Assessment is a comprehensive account of an individual's functioning in the widest sense, drawing on a variety of evidence, qualitative as well as quantitative. It is more summative in nature. The formative part is strongly supported by a solid summative component as part of the teaching process.

Conclusion

In the course of this discussion, we have seen that problem-solving means different things to different people. As a result of this, the goal of problem-solving remains vague. Equally unclear is the role that problem-solving, once adequately characterised, should play in the larger context of school and university mathematics. What are the goals of teaching mathematics, and how does problem-solving fit within those goals? (Schoenfeld 1992). However, despite this ambiguity, we succeeded in looking into two diverging schools of thought on problem-solving. The traditional approach considers problem-solving as part of mathematics teaching and learning, the aim of which is to inculcate basic skills. The proponents of this approach consider the modern approach to problem-solving as diversionary, frivolous, and a squandering of time that should be given over to 'hard work' (Ernest, 1991, p. 287). The modern approach on the other hand, considers problem-solving as a process through which mathematics is learnt. They consider mathematics as a science of patterns. Although the latter approach is gaining acceptance in the community of mathematics educators, where it is firmly established on a sound theoretical footing and is seen as promising, the major obstacle remains one of implementation. Evidence of classroom practices show that classrooms have only witnessed 'the rhetoric of problem-solving rather than its substance' (Schoenfeld, 1992).

References

BELL, F. H. (1978). *Teaching and learning mathematics (In secondary schools)*. W. M. C. Brown Company Publishers: Dubuque, Iowa.

ERNEST, P. (1991). *The philosophy of mathematics education*. Falmer Press: London.

FINE, N. J. (1966). Some thoughts on problem-solving, in *The role of axiomatics and problem solving in mathematics* (pp. 98–100). Ginn and Company: Washington, DC.

JACOBSON, F. D. (1966). The role of problems in the development of mathematical activity, in *The role of axiomatics and problem solving in mathematics* (pp. 101–105). Ginn and Company: Washington, DC.

KWARI, R. AND WESSELS, D. C. J. (2003). The nature of problem-solving in mathematics: Traditional versus contemporary views. *Tydskrif vir Christelike Wetenskap/ Journal for Christian Scholarship*, **39**(1-2), 69–93.

POLYA, G. (1966). On teaching problem-solving, in *The role of axiomatics and problem solving in mathematics* (pp. 123–129). Ginn and Company: Washington, DC.

SCHOENFELD, A. H. (1992). Learning to think mathematically: Problem-solving, metacognition, and sense making in mathematics, in D. A. Grouws (Ed.), *Handbook of research on mathematics teaching and learning: A project of the National Council of Teachers of Mathematics* (pp. 334–370). Macmillan: New York.

STANIC, G. AND KILPATRICK, J. (1988). Historical perspectives on problem-solving in the mathematics curriculum, in R. I. Charles and E. A. Silver (Eds), *The teaching and assessing of mathematical problem solving* (pp. 1–22). National Council of Teachers of Mathematics: Reston, VA.

Algebraic manipulations of polynomials using MS Excel

M. El-Gebeily and B. Yushau

Department of Mathematical Sciences, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia

In this short paper, we show how one can use MS Excel to evaluate polynomials in three different ways. Furthermore, we also show how polynomial multiplication of 'any' degree can be performed. The approach is simple to follow, and can easily be implemented in the classroom by both teachers and students.

Introduction

Polynomials are 'well-behaved' functions which are found in all levels of mathematics education from early secondary school onwards. Addition and subtraction of polynomials are easy to follow by the average student. However, on first encounter, students find multiplication of polynomials different, and in fact relatively difficult. Similarly, evaluating polynomials can be cumbersome unless they have a small number of terms, or the number we are evaluating is small and an integer. In this paper, we intend to show how one can use MS Excel to do these operations easily. The procedure needs only to be established once, and with the 'what if' capabilities built into Excel, one can then perform any multiplication or evaluation simply by changing the parameters.

In one lesson, a teacher can teach a whole range of polynomial multiplication and evaluation. Similarly, students can crosscheck their work, and have the opportunity to explore and maybe to discover patterns in the manipulations. The same can be done with synthetic division, which is equivalent to polynomial evaluation.

Since Excel is available on almost all computers, it is hoped that many teachers and students will benefit from this approach.

Polynomial evaluation

There are three different ways to do polynomial evaluation in algebra: direct substitution, nested evaluation, and synthetic division. In this section we briefly describe the three methods and show how to use Excel to implement them.

Example 1 Evaluate $P(x) = 3x^4 - 2x^2 + 5x + 7$ at $x = -4$.

1. Direct substitution method
This is the most direct method in which x is replaced by -4. Thus we obtain

$$P(-4) = 3(-4)\hat{}4 - 2(-4)\hat{}2 + 5(-4) + 7 = 723.$$

The Excel implementation of this is also straightforward. One simply selects a cell (say B3) and types the formula =3*(-4)^4-2*(-4)^2+5*(-4)+7 in the formula bar. When the Enter key is pressed, the result 723 appears in cell B3. This method, however, has the following drawbacks:

1. The number of multiplications and additions required is unnecessarily high.
2. It is numerically inaccurate; what numerical analysts call loss of significance can occur in this kind of operation.
3. The formula is tedious to retype each time the value of x changes. This can however be avoided by making reference to a cell which will hold to the value of -4. For this example, we could type the value -4 in cell A3 and modify the formula to be typed in B3 so it becomes =3*(A3)^4-2*(A3)^2+5*(A3)+7. When the Enter key is pressed, the same result, 723, appears in B3. If, however, we want to re-evaluate the polynomial at $x = 2$, for example, we simply type the value 2 in cell A3. When Enter is pressed the value in B3 immediately changes to 57.

2. Nested evaluation method
In this case the polynomial is rewritten as

$$P(x) = x(x(x(3x + 0) - 2) + 5) + 7.$$

This is called the nested form of the polynomial. Notice that 0 appears in this form because of the missing third power of x in the definition of the polynomial. Now the evaluation of this polynomial at -4 is done by successively removing the brackets starting from the innermost one. We have

$$\begin{aligned} -4(-4(-4(3(-4) + 0) - 2) + 5) + 7 &= -4(-4(-4(-12) - 2) + 5) + 7 \\ &= -4(-4(46) + 5) + 7 \\ &= -4(-179) + 7 \\ &= 723. \end{aligned}$$

With this approach we have only one multiplication and addition at each step. The number of operations is less than that of the direct evaluation approach. To implement this in Excel we take the following steps:

1. Type the value of x in one cell and the coefficients of the polynomial in the next cells in the same row as shown in Figure 1. Notice that we inserted a zero for the coefficient of the missing power of x.

2. In cell D6, type the formula =D5. The effect of this is simply to copy the value of the first coefficient of the polynomial into cell D6. The result is also shown in Figure 1.

3. In cell E6, type the formula =D6*C5+E5 and press Enter. This, in effect, amounts to the evaluation of the innermost bracket term. The result is also shown in Figure 1. Notice that the use of the dollar signs in C5 fixes the reference to this cell when we copy the formula in the next step.

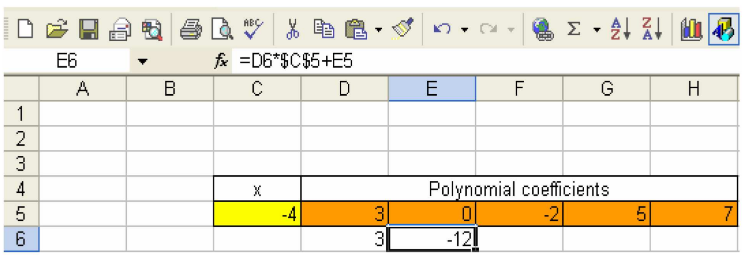


Figure 1: Nested evaluation method steps 1 to 3.

The evaluation of the outer brackets amounts to repeating the formula in step 3 above to the rest of the cells below the polynomial coefficients. This is done by selecting the cell E6, pointing to the fill handle (the little + sign at the lower right corner of the selection box), clicking and dragging over the cells F6–H6. The results are shown in Figure 2.

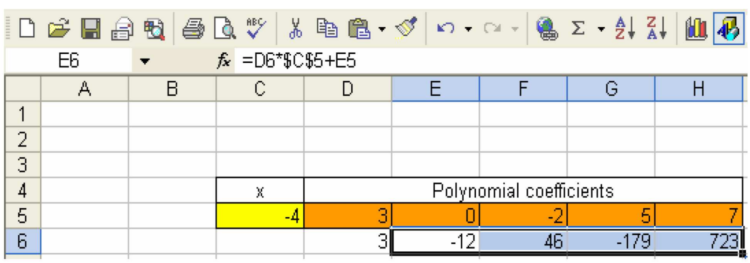


Figure 2: Nested evaluation method final result.

Notice that the value of the polynomial evaluation now appears in cell H6. If we wish to evaluate the polynomial at a different value (say 2), all we have to do is type the new value in cell C5 and press Enter, the result then appears automatically.

For a better understanding of what is going on, the reader should try to do the last two steps without typing the dollar sign $ to fix reference to C5 to see what happens.

3. Synthetic division

The method of synthetic division is, like the method of nested evaluation, designed to minimise the number of operations required to evaluate a polynomial and, practically, eliminates the loss of significance. Its origin is a reorganisation of the method of long division to eliminate all unwanted intermediate steps. The method is organised as shown below.

$$\begin{array}{r|rrrrr} -4 & 3 & 0 & -2 & 5 & 7 \\ \hline & & -12 & 48 & -184 & 716 \\ \hline & 3 & -12 & 46 & -179 & \mathbf{723} \end{array}$$

The result appears in the last cell in the above arrangement. It may be surprising to know that the method of synthetic division is implemented in Excel in exactly the same way as the method of nested evaluation. Thus steps 1–3 of the previous subsection can be followed to implement synthetic division.

Polynomial multiplication

Implementing polynomial multiplication in Excel gives rise to a better understanding of the inner workings of the process. The student would understand that every coefficient of the first polynomial multiplies every coefficient of the second one. In addition, s/he would see that multiplication by the coefficient of x results in a shift of all products one place to the right, multiplication by the coefficient x^2 results in a shift of all products two places to the right, and so on. The method is best illustrated with an example.

Example 2 Perform the multiplication

$$(14x^5 - 7x^4 + 3x^3 + 1)(4x^5 - 10x^2 + 2x).$$

The reader will notice that the following steps are designed to multiply any two polynomials of degree up to 5. The idea can be implemented for polynomials of higher degrees. The steps are: enter the coefficients of the polynomials as shown in Table 1. The entries here are written in the cells C2:H2 for the first polynomial and B3:B8 for the second polynomial. Since the result is a polynomial of degree 10, extra space has been allocated in Table 1.

In cell C3 enter the formula (=C$2*$B3) and press Enter. Notice that in this formula we need to fix row 2 and column B (by printing the dollar sign before it) since they contain the coefficients of the two polynomials. The reader should try to see what happens if this fixing is not done.

	A	B	C	D	E	F	G	H	I	J	K	L
1		**P1**	1	x	x^2	x^3	x^4	x^5				
2	**P2**		1	0	0	3	-7	14				
3	1	0										
4	x	2										
5	x^2	-10										
6	x^3	0										
7	x^4	0										
8	x^5	4										

Table 1: First step in the multiplication process.

Select cell C3, point to the fill handle and drag horizontally to copy the formula to the range D3:H3. Now select the range C3:H3, point to the fill handle and drag vertically to copy the formula to the range C4:H8. The result of these three steps are shown in Table 2. At this stage we see that every coefficient of the first polynomial multiplies every coefficient of the second one.

	A	B	C	D	E	F	G	H	I	J	K	L
1		**P1**	1	x	x^2	x^3	x^4	x^5				
2	**P2**		1	0	0	3	-7	14				
3	1	0	0	0	0	0	0	0				
4	x	2	2	0	0	6	-14	28				
5	x^2	-10	-10	0	0	-30	70	-140				
6	x^3	0	0	0	0	0	0	0				
7	x^4	0	0	0	0	0	0	0				
8	x^5	4	4	0	0	12	-28	56				

Table 2: Second step in the multiplication process.

The next step is to make the products in Table 2 coefficients of the correct powers of x (or rather put them into correct *place value*). This is accomplished by shifting row 4 one place to the right, row 3 two places to the right and so on. To shift row 4 one place to the right select it, move the cursor to one of the sides of the selection box, click and drag the selection one cell to the right. The result is shown in the top of Table 3. Now select the range C9:M9 and press the sum button on the menu bar to produce the sums

of the corresponding coefficients. The results from doing all this are shown in Table 3.

	A	B	C	D	E	F	G	H	I	J	K	L	
1		**P1**	1	x	x^2	x^3	x^4	x^5					
2	**P2**		1	0	0	3	-7	14					
3	1	0	0	0	0	0	0	0					
4	x	2		2	0	0	6	-14	28				
5	x^2	-10			-10	0	0	-30	70	-140			
6	x^3	0				0	0	0	0	0	0		
7	x^4	0					0	0	0	0	0	0	
8	x^5	4						4	0	0	12	-28	56

Table 3: Final result of performing the polynomial multiplication $(14x^5 - 7x^4 + 3x^3 + 1)(4x^5 - 10x^2 + 2x)$.

Once the table for multiplying polynomials of degree up to 5 is set, it can be used to multiply other polynomials (of degree up to 5) simply by changing the appropriate coefficients. As an example, Table 4 shows the result of the product $(1+x)(2-x+3x^2)$.

	P1	1	x	x^2	x^3	x^4	x^5					
P2		1	1	0	0	0	0					
1	2	2	2	0	0	0	0					
x	-1		-1	-1	0	0	0	0				
x^2	3			3	3	0	0	0	0			
x^3	0				0	0	0	0	0	0		
x^4	0					0	0	0	0	0	0	
x^5	4						0	0	0	0	0	0
Product		4	2	2	3	0	0	0	0	0	0	0
		1	x	x^2	x^3	x^4	x^5	x^6	x^7	x^8	x^9	x^{10}

Table 4: Final result of performing the polynomial multiplication $(1+x)(2-x+3x^2)$.

Conclusion

In this paper we have shown three different ways of evaluating polynomials using MS Excel, and have also shown how to multiply polynomials of 'any' degree. The approach can easily be implemented by teachers in teaching these topics, and will not only help

students to solve problems, but will provide them with a deeper understanding of the operations involved. Furthermore, students can easily verify their results ‘by hand’ and can explore the subject matter at a deeper level previously not possible without the aid of a computer.

Acknowledgement

The authors would like to thank King Fahd University of Petroleum and Minerals for their excellent research facilities.

Coding and decoding messages with Maple

Arselene Ayari, M. Ali Ayari and Sahbi Ayari

Mathematics Program, University General Requirements Unit, United Arab Emirates University, Al Ain, United Arab Emirates

Using only basic notions of algebra such as matrices and vectors, we show how Maple can be used to code and decode messages. By converting alphabetical characters to numerical numbers and using a secret matrix, we are able to send messages with confidentiality.

Introduction

Over the past twenty-five years, message transmission has evolved into a highly sophisticated process. Many research programmes are underway to develop robust cryptography and quantum computing teleportation procedures with direct applications to electronic communication and electronic transactions through the Internet. Basically, private information is communicated securely to the intended party in coded form, and subsequently decoded by the receiving party.

Encryption is a science concerned with data scrambling prior to transmission. The receiving side has the capability of deciphering the information through a key. The basic concept utilised in modern encryption and decryption is a dynamic one. In the static case a unique key is provided, while in the dynamic case a new key is provided on a packet-by-packet basis. There are two sides to encryption on the Internet: private key encryption, which requires the key to be kept secret, and public key encryption, which involves encoding that can be used by all authorised users on the Internet. The key for decoding is of course kept secret.

Philip Zimmerman developed Pretty Good Privacy (PGP) which is a program freely available on the Internet. Several data encryption standards have been developed over the past few years such as Data Private Facility (DPF), Data Encryption Standards (DES), which uses a challenge-response setup, and RSA, so named after its developers Rivest, Shamir and Adlemann, and is the standard used for public key encryption today. Commonly used encryption programs on the Internet are Secure Socket Layer (SSL) and Secure Hypertext Transport Protocol (SHTTP). Recently it was reported that the

laws of quantum mechanics have been used at Los Alamos Laboratories in the US to develop procedures for exchanging secret messages. Quantum mechanics makes the application much more powerful but at the same time more fragile against noise.

The purpose of this paper is to initiate students into this domain of research by using the same idea, namely that of sending a secret message, that cannot be read by intruders. We show that using basic tools such as Maple we can send a message (not a secret one) to students.

An outline of the paper is as follows. In the next section we describe the current capabilities available for sending secret messages using the Maple software package. Several routines capable of coding and decoding messages then follow. Finally, two example messages of differing size are presented.

Public key encryption with Maple

Twenty years ago, a novel cryptography scheme was developed by Ron Rivest, Adi Shamir, and Len Adlemann. This technique, now known as RSA, was the first published public key encryption system. The main idea behind their contribution was that the method of encoding a message did not include the method of decoding; the decryption key had to be kept safe from unwanted intruders and the encryption method could be readily made available to the public. The procedure uses basic algebra and is readily accessible within the Maple package (see the examples directory in Maple).

To begin with, a way of converting between letters and numbers is hand-coded. We will only use lower case letters and use the obvious mapping of $a \rightarrow 1, z \rightarrow 26$ and space $\rightarrow 27$. The following two routines do this:

```
>to_numbers:=proc(st)
>local ll,nn,ss,ii,num;
>num:=table(['a'=1,'b'=2,'c'=3,'d'=4,'e'=5,'f'=6,
>'g'=7,'h'=8,'i'=9,'j'=10,'k'=11,'l'=12,'m'=13,'n'=14,
>'o'=15,'p'=16,'q'=17,'r'=18,'s'=19,'t'=20,'u'=21,'v'=22,
>'w'=23,'x'=24,'y'=25,'z'=26,'` `'=27]):
>if not type(st,string) then
>Error(`wrong number (or type) of arguments`)
>fi;
>ll:=length(st);
>if ll= 0 then RETURN(0) fi;
>nn:=1;
>for ii from 1 to ll do
> ss:=num[substring(st,ii..ii)];
> if(not type(ss,numeric)) then
>ERROR(`wrong number (or type) of arguments`)
>fi;
> nn:=100*nn+ss;
```

```
>od;
>nn-10^(2*ll);
>end:
>from_number:=proc(nn)
>local
>ss,mm,ll,ii,ans,a,b,c,d,e,f,g,
>h,i,j,k,l,m,n,o,p,q,r,s,t,u,v,w,x,y,z
>‘ ‘,alpha;
>alpha:=table([1=a,2=b,3=c,4=d,5=e,6=f,
>7=g,8=h,9=i,10=j,11=k,12=l,13=m,14=n,
>15=o,16=p,17=q,18=r,19=s,20=t,21=u,22=v,
>23=w,24=x,25=y,26=z,27=‘ ‘]):
>mm:=nn;
>if(not type(nn,integer) then
>ERROR(‘wrong number (or type) of arguments‘)
>fi;
> ll:=floor(trunc(evalf(log10(mm)))/2+1;
>ans:=‘‘;
>for ii from 1 to ll do
>mm:=nm/100;
> ss:=alpha[frac(mm)*100];
>if(not type(ss,string)) then
>ERROR(‘wrong number (or type) of arguments‘)
>fi;
> ans:=cat(ss, ans);
> mm:=trunc(mm)
> od;
> ans;
> end:
# Here is an example of how these routines are used
> to_number(‘maple’);
> from_number(805121215);
```

The mathematics now follows. The trick that makes public key encryption work is the fact that very large integers are extremely difficult to factor. Thus, if we release a large integer with only two large prime factors into the public domain the chances are very good that an adversary will not be able to factor it. In the following examples, the primes are kept much smaller than would be used in actual cryptography where the two prime factors are typically of the order of 10^{100}.

The first step is to select two large primes. Maple has a function that will return the next prime after a given integer, and we will use it to get our primes.

```
>p:=nextprime(7347124781320478301247);
```

```
>q:=nextprime(4785748390275423890557842355347820 43);
```

One of the numbers released as the public key is the integer $n = p * q$ where p and q are the two large primes we have just selected.

We now calculate the Euler phi function n, this being the number of integers less than or equal to n that are co-prime to n. Since the factorisation of n is known, we can easily compute this number, $(p-1)*(q-1)$. Maple has a built-in function that will compute the phi function for any integer, but it must factor the integer, and this takes a long time, even when n is small!

```
>n=p*q;
>phi_n:=(p-1)*(q-1);
```

Now we select another integer, e, between 2 and $phi(n)$, that is co-prime to $phi(n)$. This should be easy if we pick e to be prime and just perform division on $phi(n)$ to ensure it is not a factor.

```
>e:=nextprime(432432);
>evalf(phi_n/e);
```

Next we must solve a linear diophantine equation and this is the place where a little algebra enters our problem. This has a solution since e was chosen to be co-prime to $phi(n)$. Furthermore, the solution is a single congruence class modulo $phi(n)$ so there is exactly one number d between 1 and $phi(n)$ that will solve the equation.

```
>igcdex(e,phi_n,'d','k');
>d:=d mod phi_n;
```

Now we have all the parameters for encryption and decryption. We release the numbers n and e into the public domain while keeping the number d safe to use in decryption. The numbers p, q and $phi(n)$ can be discarded as they are not needed for decryption but must not be revealed either, as they can be used to compute d.

To encode a message, the user turns the message into an integer M and then breaks it up into chunks less than or equal to n. This will be no problem in our case as we will not encode anything longer than 30 letters or so. The user then computes the remainder of our first example using the short message

```
>M:=to_number(`hi');
```

Note, however, given the huge size of e, we cannot hope to compute the power directly. However, Maple's mod function is smart enough to handle each step of the power to something it can handle.

```
>C:=Power(M,e) mod n;
```

This is what we send for our message. Note that our short message has now become quite long. This does not mean that slightly longer messages will take up even more

space, since every M is set to exactly one integer between 1 and n, so the message cannot be any longer than n.

To decode the message we use the integer d and a little more algebra. All we compute is C^d mod n. This will give us not only a number between 1 and n, but indeed the message itself!

```
>Power(c,d) mod n;
>from_number(");
```

The proof that this is always true can be readily shown. The proof involves Fermat's little theorem and the Chinese remainder theorem – both of which have been known for hundreds of years. However, tools like computers (and Maple!) have not been around that long, and they are the key to finding large primes and performing the calculations. There has not yet been a proof that the only way to decrypt C is to factor n and determine d, despite the work of many mathematicians. This method cannot be considered safe until such a proof becomes available. If anyone has discovered an easier way to decode the message, they are obviously not telling anyone!

As a final example, we will encode a longer message from Rene Descartes.

```
>M:=to_number(`i think therefore i am`);
>Power(M,e) mod n;
>Power(c,d) mod n;
>from_number(");
```

Matrix mapping encryption procedures

In this section we propose a simple, yet efficient method for message encryption. Maple, version 5, has been used in the development of this program and all the functions and commands are as described in the Maple V library reference manual (Chas, Geddes, Gonnet, Leong, Monagon and Watt, 1991).

The program is composed of four procedures. The first procedure is named *message*. Its function is to convert the message to be coded into an array of numbers and subsequently multiplies the obtained numerical array by a secret, arbitrarily chosen array. The second procedure, *code*, defines the secret matrix which must be made available to the receiving party. There are an infinite number of ways to define the secret matrix. Of course, the more complicated the secrete matrix is, the better it will be. Next, the procedure *invpro* inverts the secret matrix which must be non-singular, i.e. $det(SecMtx) \neq 0$. Multiplying the inverted secret matrix by the coded message, we obtain the numerical message intended to be sent over a public domain such as the Internet. Finally, using the routine *decode*, and the secret message, the receiving party obtains the original message. We suggest the message is written in an array format having n rows and p columns. The words which are written in capital letters will be separated by the letter s. For now, it is up to the user to choose the values of n and p. Note this step can be made automatic so that text is tabulated seamlessly into an n by

p array. For simplicity we name the communicating parties as **A** and **B**:
To be sent by **A**:

$$\underbrace{\begin{bmatrix} \text{Secret} \\ \text{Matrix} \end{bmatrix}}_{(n,n)} \times \underbrace{\begin{bmatrix} \text{Numerical} \\ \text{Message} \end{bmatrix}}_{(n,p)} = \underbrace{\begin{bmatrix} \text{Coded} \\ \text{Message} \end{bmatrix}}_{(n,p)}$$

To be read by **B**:

$$\underbrace{\begin{bmatrix} \text{Secret} \\ \text{Matrix} \end{bmatrix}^{-1}}_{(n,n)} \times \underbrace{\begin{bmatrix} \text{Coded} \\ \text{Message} \end{bmatrix}}_{(n,p)} = \underbrace{\begin{bmatrix} \text{Numerical} \\ \text{Message} \end{bmatrix}}_{(n,p)}$$

Examples

To execute the code *message* we first need to read it into a Maple session

```
>read(message);
```

then we enter the message that we would like to send and convert it to a numerical one by executing

```
>message(4,9,[M,A,P,L,E,s,s,I,S,T,H,E,s,s,
>B,E,S,T,S,Y,M,B,O,L,I,C,s,L,A,N,G,U,A,G,E,s]);
```

Doing so we obtain the following numerical matrix where all the message letters have been replaced by numerical values and multiplied by the matrix code

$$\begin{bmatrix} 81 & 60 & 57 & 13 & 88 & 29 & 44 & 31 & 1 \\ 36 & 20 & 52 & 28 & 62 & 12 & 18 & 3 & -1 \\ 39 & -14 & 38 & 29 & 16 & -9 & 3 & 39 & 58 \\ 86 & 43 & 57 & 31 & 9 & 15 & 12 & 63 & 97 \end{bmatrix}$$

Now it is the turn of the receiving party **B** to read the message. First, **B** has to multiply the inverse of the code matrix by the previous one. It is obvious that both sides **A** and **B** must have the code matrix. Therefore writing

```
>multiply(inverse(code(4)),E1);
```

we get

$$\begin{bmatrix} 13 & 1 & 16 & 12 & 5 & 0 & 0 & 9 & 19 \\ 20 & 8 & 5 & 0 & 0 & 2 & 5 & 19 & 20 \\ 19 & 25 & 13 & 2 & 15 & 12 & 9 & 3 & 0 \\ 12 & 1 & 14 & 7 & 21 & 1 & 7 & 5 & 0 \end{bmatrix}$$

Finally, by executing the following command

```
>decode(%,4,9);
```

where $\%$ means the previous result from the Maple session is used, we obtain

$$\begin{bmatrix} M & A & P & L & E & s & s & I & S \\ T & H & E & s & s & B & E & S & T \\ S & Y & M & B & O & L & I & C & s \\ L & A & N & G & U & A & G & E & s \end{bmatrix}$$

Here is another example with larger size. We would like to send the following message

```
>message(4,9,[M,A,P,L,E,T,E,C,H,H,A,S,s,s,s,T,H,E,
>R,E,S,P,O,N,S,E,s,F,O,R,s,s,Y,O,U,R,S,Y,M,B,O,L,I,C,s,
>P,R,O,B,L,E,M,S,s]);
```

Using *message* we obtain the coded version

$$\begin{bmatrix} 205 & 245 & 222 & 38 & 145 & 156 & 199 & 185 & 51 \\ 156 & 182 & 151 & 42 & 113 & 140 & 113 & 127 & 39 \\ 108 & 117 & 121 & 18 & 61 & 90 & 83 & 93 & 39 \\ 118 & 56 & 130 & 58 & 69 & 71 & 94 & 50 & 16 \\ 115 & 25 & 179 & 80 & 47 & 126 & 137 & 83 & 65 \\ 166 & 61 & 247 & 108 & 73 & 199 & 188 & 88 & 96 \end{bmatrix}$$

Once the message is received the following command is executed

```
>multiply(inverse(code(6)),E1);
```

to get

$$\begin{bmatrix} 13 & 1 & 16 & 12 & 5 & 20 & 5 & 3 & 8 \\ 8 & 1 & 19 & 0 & 0 & 0 & 20 & 8 & 5 \\ 18 & 5 & 19 & 16 & 15 & 14 & 19 & 5 & 0 \\ 6 & 15 & 18 & 0 & 0 & 25 & 15 & 21 & 18 \\ 19 & 25 & 13 & 2 & 15 & 12 & 9 & 3 & 0 \\ 16 & 18 & 15 & 2 & 12 & 5 & 13 & 19 & 0 \end{bmatrix}$$

Finally, using

```
>decode(%,6,9);
```

we obtain what side **A** sent

$$\begin{bmatrix} M & A & P & L & E & T & E & C & H \\ H & A & S & s & s & s & T & H & E \\ R & E & S & P & O & N & S & E & s \\ F & O & R & s & s & Y & O & U & R \\ S & Y & M & B & O & L & I & C & s \\ P & R & O & B & L & E & M & S & s \end{bmatrix}$$

Concluding remarks

There are many different ways to further complicate an encrypted message so as to make it harder to be read by intruders. Further complication on the procedure described above can be achieved if one, or all, of the following is changed. While assigning numbers to each of the alphabetical letters, one might always find a formula that makes such a task even more complicated. Such modification should be done within the procedure *Numeric*. Also, as there are infinitely many ways to construct the code matrix *secMtx*, this makes the coded message that much harder to crack. Adding different characters or using rational or real numbers would also contribute considerably to the secrecy of the message. Finally, questions addressed to the students concerning changing the code matrix and the assigned numbers to letters can also be asked and explored.

References

CHAR, B. W., GEDDES, K. O., GONNET, G. H., LEONG, B. L., MONAGON, M. B. AND WATT, S. M. (1991). *Maple V library reference manual*. Springer-Verlag: New York.

e-Math test bank

K. Khalil and M. Odeh

Mathematics Program, University General Requirements Unit, United Arab Emirates University, Al Ain, United Arab Emirates

In this paper we introduce a remarkable automated procedure to generate computer based examinations. The procedure is a hybrid between high quality LaTeX output and scalable vector graphics. Time wise, the only limitation is the natural limitations of the PC used to run the procedure. Using the procedure, we show how to construct an e-Math test bank which contains pools of questions used to generate different tests.

Introduction

Computer and Internet based tests are used for a variety of purposes. From entering education or employment, to improving basic learning, people everywhere are taking electronically-formatted tests. Examples of such tests include:

- placement examinations;
- exit examinations for grade-level or graduation;
- SATs, ACTs or GREs for tertiary-level entrance;
- national or international board examinations across disciplines;
- Microsoft, Novell, IBM, and other technical certifications;
- management certifications used throughout the business world;
- professional development and hiring examinations;
- ongoing examinations used in public schools and institutions of higher education for continuous student improvement and curricular outcomes-based testing.

With the advancement of testing from traditional paper-based tests to technologically advanced electronic tests, people reap the benefits of easier access to tests, faster response times, and greater reliability and validity of tests.

The use and re-use of mathematical and scientific content on the Internet, and for other applications such as computer algebra systems, print typesetting is a real challenge. It comes from the need of presentation of mathematical notation for high-quality visual display. Many markup languages, such as MathML, were developed to solve this problem. MathML consists of a number of XML tags which can be used to mark up an equation in terms of its presentation and also its semantics. Another language is scalable vector graphics (SVG), a language for describing two-dimensional graphics in XML. SVG is positioned to have a major impact on web graphics because it enables resolution independent graphics rendering either from static text files or when generated from databases as it leverages many of the useful features of the XML family of specifications. SVG allows for three types of graphic objects: vector graphic shapes (e.g., paths consisting of straight lines and curves), images, and text. Graphical objects can be grouped, styled, transformed, and composted into previously rendered objects. The feature set includes nested transformations, clipping paths, alpha masks, filter effects, and template objects. SVG drawings can be interactive and dynamic. Animations can be defined and triggered either declaratively (i.e., by embedding SVG animation elements in SVG content) or via scripting. Your web browser should have the SVG viewer. If not, it can be downloaded from Adobe's website.

Our research focused on putting LaTeX quality and SVG high level features together to create an electronic mathematics test bank that could be used on the web, under Blackboard, or any other content management software package. How can an institution build a test bank that uses mathematical formulae, pictures and graphics in an easy and none-expensive way without spending large amounts of time and without the need for experts in mark up languages?

In this article we introduce a very easy and reliable method to generate such a test bank. The method was developed during the past year when we built a mathematics test bank for the mathematics programme of the University General Requirements Unit (UGRU) at United Arab Emirates University (UAEU). We used in-house generated software called CGE-freeware software as the interface. The test bank structure is discussed in the next section where it addresses the administrative requirements and needs in the test, feedback about the difficulty levels, and related issues. The following section discusses in detail the construction and organisation of the bank in a way that meets the requirements discussed in the previous section. In the final section we explain the full procedure of putting all the elements together using a scripting language (Perl).

Math test bank work flow

Math test bank consists of three test banks, one for each of the three courses taught in UGRU. A test bank committee is in charge of running the work on the test bank. In addition to the test bank coordinator (TBC), the committee consists of three members (TBCM), a teacher for each course, and usually the same teacher is a test committee member. Supervised by course coordinators, TBCMs create questions for each of his/her own course. Questions are then submitted to the TBC who typesets a summary file for each question. Summary files, either hard or soft copies, are returned back to prospective test coordinators for approval. Once summary files are approved, the TBC updates the test banks with the new questions. To maintain question status in test banks, summary files are printed and stored in a test bank binder (one binder for each course). This binder includes a section with statistics on each question from previous examinations. When an examination is to be done, a course coordinator will browse through the test bank binder, identifying examination questions by summary file name. A list of required questions is then submitted to the TBC who in turn generates a CGE. The CGE is tested by testing committees and course coordinators for verification of format, marks and expected time needed for the examination.

Automatic test bank processing

Test bank folders are organised and named so as to match with the structure of the *area content* part of the course core competencies (CCC). The reason behind basing the numbering scheme on the CCC and not on the chapter or section numbering of the textbook being used is that different textbooks typically cover the same content at slightly different places. On the other hand, the CCC is a stable course document that does not depend on any particular textbook used in the course. Thus changing textbook does not effect the question numbering used in the test banks. The area content part includes main course objectives (e.g. 1 Solve equations and inequalities), performance sub-objective (e.g. 1.1 Solve linear equation) and teaching and learning objectives (e.g. 1.1.1 Solve linear equations involving absolute values). To clarify the naming scheme adopted, a sample of a test bank folder tree is shown in Figure 1.

The naming convention is thus obvious. Folder 1.1 includes questions that cover objective 1.1 in the CCC. Folder 11e1 contains the summary file of the first easy question on 1.1. Other possibilities for difficulty of questions are ‘em’ (easy medium), ‘m’ (medium), and so forth. Note that these classifications are just a rough first guess. Only statistical data, when collected on individual questions, will show the real difficulty level of any particular question. To track teaching and learning objectives of the CCC, we label each summary file at the top right hand corner of its heading by the number of that objective.

Besides classification according to area content, questions are classified according to the cognition level and thinking skills students are expected to use to respond cor-

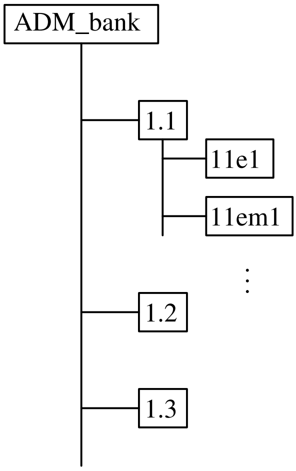


Figure 1: Sample of a test bank folder tree.

rectly. For this purpose the TIMSS[1] performance expectation scheme is adopted. The scheme consists of five different levels, namely:

1. knowing;
2. using routine procedures;
3. investigating and problem-solving;
4. mathematical reasoning;
5. communicating.

As an example, a heading of a summary file is given in Figure 2.

The last three rows in Figure 2 at the bottom of the heading show the usage history of each question in the bank. In the usage part, T1F04 stands for Test1 of Fall04. PP stands for percentage of students who responded correctly to that question. Finally, TC stands for the average time taken by students to respond to that question (this is usually provided by the ITS). The history of the question is of great importance when selecting questions for a test. According to those entries, the total passing rate in the examination can be expected and somehow controlled. Besides, an estimated time needed for the test can be known. Across the bottom of the summary file we document the course name, date the summary file was generated, and verification boxes that are ticked when the question is finally approved by the TBC and the CCC.

[1]Trends in International Mathematics and Science Study. See http://timss.bc.edn

1. Solve equations and inequalities						111
Performance objective			Cognition Level			
1.1 Solve linear equations			Knowing and using routine procedures			
Usage	T1F04					
PP	54%					
TC	180 sec					

Figure 2: Heading of a summary file.

The main body of the summary file includes versions of the same question. The number of versions is not restricted, however we usually use three versions. When a test is run, the CGE is written to select randomly one of the versions and randomise the distracters and questions. This literally generates a huge number of versions of the same test.

Assuming that questions to be included in the test are selected by the CCC; the procedure to create a CGE starts by copying the corresponding folders to the exam directory. Each folder contains the summary file (*.tex) and any additional supporting file of the selected question. The procedure applies to one summary file at a time. The output of the procedure will be individual SVG files for every question and distracter in the summary file, and CGE code. So by applying the procedure on a summary file with three different versions, sixteen SVG files and a single CGE file are produced. In theory, this requires many tedious intermediate steps. However, most of the labour is automated. The overall flow of the procedure is shown in Figure 3.

Time estimated to execute this procedure is on average no more than four minutes. The only limitation one may face is the PC's natural memory limits. *Makeall.pl* is a Perl script that produces individual pdf files for every question and distractor in the summary file. In fact, this script is the heart of the whole process. It does most of the work which, if done manually, would take quite a long time to complete. This script is run from the cmd prompt in the appropriate directory where the summary file resides (`c:\ ...\11em1>makeall.pl`). The script reads the summary file which is marked up, as shown in Figure 4, so that the script identifies questions, their answers, and distractors.

Once the script counts the number of questions and their distractors, it starts to slice the summary file and writes *.tex files for every question and distractor. The only difference in the *.tex files for questions and distractors are the dimensions of the pdf templates. For the distractors, the width and height are 213 by 40, which will be magnified by 1.5 when converted to SVG (320 by 60). This results in a 2 by 2 distracter array. For the questions, the important dimension is the width, which is of 450 points. When magnified, the width of the SVG template becomes 675 points, which fits nicely into the CGE program. The height of the question template is rather arbitrary as the

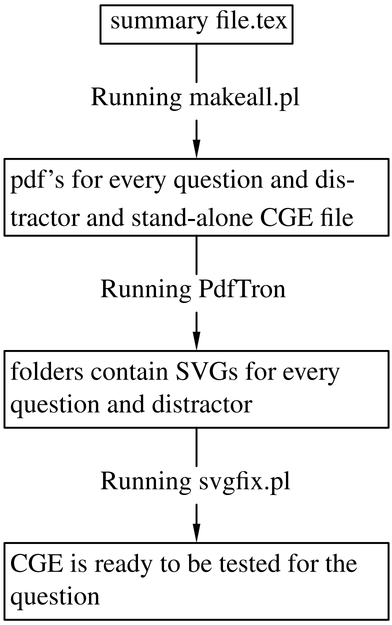


Figure 3: Overall flow of technical procedures.

amount of available vertical space will vary according to the size and configuration of the distractor boxes. In fact, these dimensions are chosen to have a nice looking configuration in the CGE program, however, in certain cases, especially when graphs are included, one needs to modify both dimensions and configuration. The makeall.pl script has optional width and height arguments. These will affect the size and thus the configuration of the distractors boxes. The default is a standard size of 213 by 40. Question files are named 11e1_1q.tex, 11e1_2q.tex, etc. The associated distractor files are named 11e1_1a.tex, 1b, etc., with the correct answer normally being 'a'.

Next, the script will automatically PdfLaTeX these tex files to produce pdf's. Along with this process, makeall.pl writes a small stand-alone CGE (e.g. 11e1.cge). This CGE is used to test the format of each question. A typical CGE code is shown in Figure 5.

PdfTron

This is a commercial program for batch conversion of pdf to SVG. We use PdfTron to convert pdf flies created by maleall.pl to SVGs. However, PdfTron creates a subdirectory and file name like 11e1_1q-1 for every pdf file. As we do not need to change the names of the SVG files, because CGE code is written using these names, we need one more step to correct this side effect of the conversion process.

```
\item
%%Question
Solve for $x$:\quad $1-|x-1|=-2$
%%EndQuestion

\begin{multicols}{2}
\begin{hsublist}
\item
%%Answer
$x=4$ or $x=-2$
%%EndAnswer
\item
%%Distractor
$x=-4$ or $x=2$
%%EndDistractor
⋮
\end{hsublist}
\end{multicols}
```

Figure 4: Summary file markup.

svgfix.pl
This script fixes the problem generated in the former step. It recursively enters the subdirectories, renames the files, moves them up one directory, and deletes the old subdirectories. It also magnifies SVG files by 150% to get the desired size and cleans up all irrelevant files (*.out, *.log, etc.) produced when PdfLaTeX takes place. Once this is done for all selected problems in the test, the examination is created by copying SVG files to a new blank examination directory. The CGE code is created by copying and pasting code fragments from the stand-alone code for every question. The examination is now ready to be run.

Conclusion

In this paper we introduced a simple procedure to generate computer based examinations. The importance of this procedure is in its high efficiency in producing CGEs with the use of high quality tools such as LaTeX and SVG in a relatively short period of time compared to other known procedures. The procedure can be used not only to generate mathematics CGEs, but it suits any course. We have been using this procedure to generate our examinations for more than two years now. So far, the process has proved to be accurate and almost error-free.

Besides test banks used in regular examinations, practice tests are generated and made available for students prior to each test. Placement examinations are also gener-

```
Group=11e1
GroupRandom=Yes
RandomChoices=Yes
q=file:11e1_1q.svg
ca=file:11e1_1a.svg
h=60
w=320
c=file:11e1_1b
h=60
w=320
c=file:11e1_1c
h=60
w=320
c=file:11e1_1d
h=60
w=320
```

Figure 5: Typical CGE code.

ated by the same technique. Currently, a project of unifying all mathematics entrance examinations at all universities within the United Arab Emirates, where about 4000 students take such an examination each year, is under discussion. Once it is approved we expect our procedure described for generating examinations will be one of deciding factors which influences universities to move towards unifying their mathematics entrance examination process.

Acknowledgements

This work was strongly supported by the UGRU Dean, Academic Services, and by the Mathematics Program Head. Also, we would like to thank Dr David Lane who did a remarkable job in his contribution to the development of the Perl script used, and in the structure of the test bank adopted. We would also like to express our thanks to all mathematics teachers in the mathematics programme for their support and encouragement through out the project. Finally, our thanks go to Mr Christopher Head for his support and flexibility in modifying the CGE software thereby making this work possible.

Using concrete and semi-concrete modelling: Justification and explanation in teaching mathematics in a classroom-community-based learning environment

Medhat H. Rahim

Faculty of Education, Lakehead University, Thunder Bay, Canada

One of the most striking ways of explaining mathematical concepts effectively is through the use of manipulation and model representations. Andrew (1995) argues that unless students are offered opportunities that encourage them to explore mathematical proofs, little progress is likely to be made in mathematics at secondary level. Batista and Clements (1996) discuss the relative emphasis that formal proof should play in secondary school geometry. They argue that the theories of Piaget and van Hiele suggest that the explicit study of axiomatic systems is unlikely to be productive for the vast majority of students in secondary school geometry: students must pass through lower levels of geometric thought before they can attain a higher level, and this passage takes a considerable amount of time. Teachers, through manipulation and modelling, can convey, prove, and explain mathematical ideas and solve problems operatively in such a way that a combination of hand and mind processes are present in their classrooms.

Background

The National Council of Teachers of Mathematics (NCTM, 2000) has published its document known as *Principles and standards for school mathematics*. This document is intended to be a resource and guide for all who make decisions that affect the mathematics education of students in pre-kindergarten through grade 12. The recommendations in this document are grounded in the belief that all students should learn important mathematical concepts and processes with understanding.

For a ‘vision of school mathematics’, the NCTM (2000) states:

> Imagine a classroom, a school, or a school district where all students have access to high-quality, engaging mathematics instruction. There are ambitious expectations for all, with accommodation for those who need it.

> Knowledgeable teachers have adequate resources to support their work and are continually growing as professionals. The curriculum is mathematically rich, offering students opportunities to learn important mathematical concepts and procedures with understanding. Technology is an essential component of the environment. Students confidently engage in complex mathematical tasks chosen carefully by teachers. They draw on knowledge from a wide variety of mathematical topics, sometimes approaching the same problem from different mathematical perspectives or representing the mathematics in different ways until they find methods that enable them to make progress. Teachers help students make, refine, and explore conjectures on the basis of evidence and use of a variety of reasoning and proof techniques to confirm or disprove these conjectures. Students are flexible and resourceful problem solvers. Alone or in groups and with access to technology, they work productively and reflectively, with the skilled guidance of their teachers. Orally and in writing, students communicate their ideas and results reflectively. They value mathematics and engage actively in learning it (p. 3).

Highlights of the vision

In other words, the NCTM (2000) vision for school mathematics highlights the following four essential aspects of school mathematics:

- Knowledgeable teachers have adequate resources to support their work and are continually growing as professionals.
- The curriculum is mathematically rich, offering students opportunities to learn mathematical concepts and procedures with understanding.
- Technology is an essential component of the environment.
- Students confidently engage in complex mathematical tasks chosen carefully by teachers.

But the question remains, how is this ambitious vision to be achieved? The NCTM only offers a description of its vision focusing on the four main components of its vision in addition to the description of the strands for elementary, middle, and high school mathematics. There exist no defined teaching materials for each of these three stages of school mathematics. It seems it is left to the teacher to prepare what he or she sees fit within the guidelines indicated. To be sure, this is no easy task; it is an extra load on the teachers who are already overloaded in their attempt to meet existing curriculum expectations as set down by their educational institutions.

The NCTM, in summary, describes the following:

> ***The students***: Draw on knowledge from a wide variety of mathematical topics, sometimes approaching the same problem from different mathematical perspectives or representing the mathematics in different ways until they find methods that enable them to make progress.
>
> ***The teachers***: Help students make, refine, and explore conjectures on the basis of evidence and use of a variety of reasoning and proof techniques to confirm or disprove these conjectures.
>
> ***The curriculum***: Is mathematically rich with opportunities for understanding.
>
> ***The environment***: In a classroom-based-community, students are flexible and resourceful problem solvers. Alone or in groups and with access to technology, they work productively and reflectively, with the skilled guidance of their teachers. Orally and in writing, students communicate their ideas and results reflectively. They value mathematics and engage actively in learning it. (NCTM, 2000, p. 3).

These four pillars represent a challenge for the mathematics education community to implement, and require effort and time if attempting to engage in such honorable tasks. The author believes that conjecturing and verifying to explain mathematical concepts through physical manipulation, and the use of technology, is one of the most effective ways in attempting to try and implement the NCTM's vision.

Conjecturing and proving

Conjecturing, verifying, proving, and explaining are at the heart of the mathematical thinking processes envisioned by the NCTM. In fact, proof is at the heart of mathematical thinking, and deductive reasoning, which underpins the process of proving, exemplifies the distinction between mathematics and the empirical sciences (Healy and Hoyles, 1998, 1999, 2000; Hoyles and Healy, 1999a, 1999b).

There is a need here to examine what the research findings suggest on these aspects of proving, deductive reasoning, and verifying to explain mathematical concepts. Healy and Hoyles (1998) state as one of their main findings that far too many students have little idea of the proving process and no sense of proof, which can hinder their ability to construct and correctly evaluate proofs. Batista and Clements (1996) discuss the relative emphasis that formal proof should play in secondary school geometry. They argue that the theories of Piaget and van Hiele suggest that the explicit study of axiomatic systems is unlikely to be productive for the vast majority of students in secondary school geometry. Students must pass through lower levels of geometric thought before they can attain a higher level, and such a passage takes a considerable amount of time. However, alternatives to axiomatic approaches can be successful in moving

students toward meaningful justification of ideas. Alternative approaches involve students working co-operatively, making conjectures, resolving conflicts by presenting arguments and evidence, explaining non-obvious statements, and formulating hypotheses to prove. Hanna (1989) has suggested that teachers should be aware of the potential that proofs have of explaining as well as verifying mathematical statements. Others (e.g., de Villiers 1991, 1992, 1997) have conducted empirical studies which lend support to this suggestion. Stiener (1978) stated that a proof explains when it shows the 'characteristic property' entailed in the theorem it purports to prove. Reid (1995) went further and indicated that this characteristic, of revealing the underlying principles on which the proof rests, is certainly a part of what makes proving a useful way of explaining for students.

In view of these research findings and the author's previous work (see, for example, Rahim, 2003, 2005) it would be more appropriate to use exploration, construction, conjecturing, and modelling mathematical concepts both physically and technologically through computer animation, in the classroom. What follows are a few examples in this direction.

Examples

Example 1

Verify through the use of algebraic tiles (physical manipulation) the validity of the following algebraic equalities:

$$\begin{aligned} \text{(i)} \quad (x+2)(x+3) &= x^2+5x+6 \\ \text{(ii)} \quad (x+3)(2x+1) &= x^2+7x+3. \end{aligned}$$

This example was demonstrated at the conference session using algebraic tiles (the colourful, plastic, see-through tiles; large $x \times x$ squares, $x \times 1$ rectangles, and smaller 1×1 squares).

Exploration: Is there a way to represent the trinomial as a product of two binomials other than the foil rule?

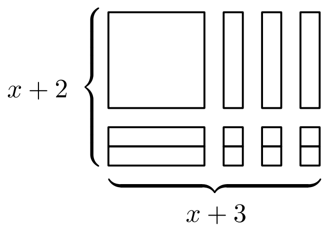
Answer: A trinomial and its two binomial factors can be represented by a rectangle. This is known as the geometric representation of trinomials.

Example 2

Using Geometer's SketchPad (GSP) to show that the angle sum of any triangle is equal to $180°$.

This example was demonstrated during the conference session. $\triangle ABC$ was constructed using the GSP *segment* command and the measures of the three angles were calculated by the GSP *measure-angle* command. Point A was animated by the GSP *display-animate* command and gave various values for the angles $\angle ABC$, $\angle BCA$, and $\angle CAB$, while their sum remained equal to $180°$. In Figure 2 are the readings for the values of the three angles when the vertices were taken at the positions shown.

(i) $(x+2)(x+3) = x^2 + 5x + 6$



(ii) $(x+3)(2x+1) = x^2 + 5x + 6$

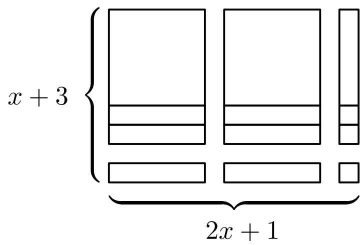


Figure 1: Geometric visual illustration for an exploration of representing a trinomial of second degree as the product of its two binomial factors using algebraic tiles.

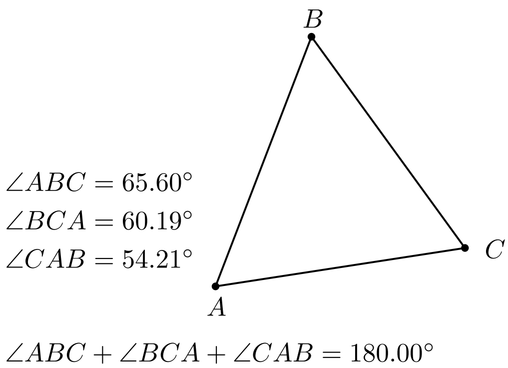


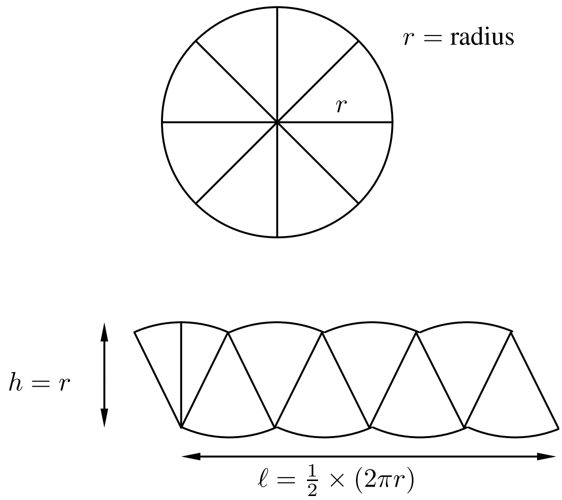
Figure 2: Angle readings for a triangle obtained from Geometer's Sketchpad.

When the audience asked whether this is a proof or a conjecture, the answer was one of conjecture. The audience however agreed that this would be sufficient for the purpose of convincing lower secondary school students that the angle sum of a triangle

is always equal to $180°$.

Example 3

Using manipulation to show, (a) the origin of the number π (a constant ratio), and (b) the area of the circle.



h = height
ℓ = length (half the circumference)

Figure 3: A circle of radius r which is then cut into eight equal segments to form an approximate parallelogram.

Part (a) was explained during the conference session where students in a classroom can prepare a table of measured values for the circumference and diameter for any number of different circular items such as, sticky-tape roll, a CD disc, a circular container, etc., and then find the ratio between the circumference and diameter for each item. The results should give a sequence of values slightly more or less than the number three. The results are indications that the ratio tends to converge to a value approximately equal to 3.14, a constant ratio for all circles we call π.

Part (b) was demonstrated in the conference session where the bottom of the shapes in Figure 3 resembles that of a parallelogram and is approximately equal in area to that of the circle, thereby allowing the area of a circle to be found. Since the base of the parallelogram has a length ℓ equal to half the circumference of the circle and its height h is equal to the radius of the circle, one has, as expected, for the area A

$$A \simeq \ell \times h = \frac{1}{2} \times (2\pi r) \times r = \pi r^2.$$

Example 4

Using manipulatives to show that the angle sum of a triangle equals 180°.

This example is based on a session which I gave at the *Canadian Mathematics Education Study Group* (CMESG) Conference at Regina University in Canada (Rahim, 1994) and is currently being considered for a forthcoming article in 'Proof without Words'.

It was demonstrated at the METSMaC conference session where a square piece of paper, a pair of scissors, and a ruler were provided to each participant. Through presenter guidance, the following steps were implemented:

1. Point E was selected at random at the upper edge of square $ABCD$.

2. The mid-point F of the right edge of the square paper was marked using paper folding.

3. Similarly, the mid-point G of the left edge of the square was marked.

4. Joining the point E with each of the mid-points F and G by line segments.

5. From step 4 we have created three angles, say X, Y and Z, as shown in Figure 4, where the sum $\angle X + \angle Y + \angle Z = 180^\circ$.

6. Cutting along the two line segments EF and EG, made in step 4, to have three pieces: upper right (triangle EBF), upper left (triangle EAG) and the remains of the original square (five-sided figure $EFCDG$).

7. Using the mid-points E and G as turning centres, turn the upper right triangle EBF to the right 180° and turn the upper left triangle EAG to the left 180° to have the three pieces form a triangle with X, Y, and Z as its angles.

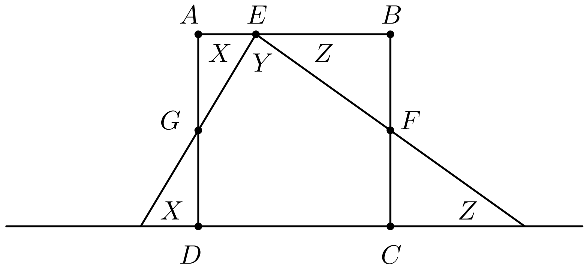


Figure 4: Manipulative example used to show that the angle sum of a triangle is 180°.

References

ANDREW, P. (1995). Proof in secondary mathematics: The necessary place of the concrete, *Mathematics in School*, **24**, 40–42.

BATISTA, M. T. AND CLEMENTS, D. H. (1996). Geometry and proof, *Mathematics Teacher*, **89**, 386–388.

DE VILLIERS, M. (1997). The role of proof in investigative, computer-based geometry: Some personal reflections, in J. King and Schattschneider (Eds), *Geometry Turned On! Dynamic Software in Learning, Teaching, and Research* (pp. 15–24). The Mathematical Association of America: Washington, DC.

DE VILLIERS, M. (1991). Pupils' need for conviction and explanation within the context of geometry, *Pythagoras*, **26**, 18–27.

DE VILLIERS, M. (1992). *Children's acceptance of theorems in geometry*. Poster presented at The Sixteenth Annual Conference of the International Group for the Psychology of Mathematics Education. Durham, NH.

HANNA, G. (1989). Proofs that prove and proofs that explain, in *Proceedings of the Thirteenth International Conference on the Psychology of Mathematics Education* (pp. 45–51). Paris.

HEALY, L. AND HOYLES, C. (1998). *Justifying and proving in school mathematics: Summary of the results from a survey of the proof conceptions of students in the UK* [online].
Available from: http//www.lettredelapreuve.it

HEALY, L. AND HOYLES, C. (1999). Visual and symbolic reasoning in mathematics: Making connections with computers?, *International Journal of Mathematical Thinking and Learning*, **1**(1), 59–84.

HEALY, L. AND HOYLES, C. (2000). A study of proof conceptions in algebra, *Journal for Research in Mathematics Education*, **31**(4), 396–428.

HOYLES, C. AND HEALY, L. (1999a). Students' views of proof, *Mathematics in School*, **28**(3), 19–21.

HOYLES, C. AND HEALY, L. (1999b). Can they prove it?, *Mathematics in School*, **28**(4), 10–11.

NATIONAL COUNCIL OF TEACHERS OF MATHEMATICS (NCTM) (2000). *Principles and standards for school mathematics*. NCTM: Reston, VA.

RAHIM, M. H. (1994). *Visual proof that the sum of the angles of a triangle is* $180°$. Canadian Mathematics Education Study Group (CMESG) Conference, Regina University, Canada, 4–8 June 1994.

RAHIM, M. H. (2003). A new proof of the Pythagorean using compass and unmarked straight edge, *International Journal of Mathematical Education in Science and Technology*, **34**(1), 144–150.

RAHIM, M. H., BOPP, D. AND BOPP, J. (2005). Shape transforms through dissection-motion-operations in two- and three-dimensional Euclidean spaces: Hands-on activities and computer animation, *International Journal of Learning* (in press).

REID, D. (1994). *"Why 4?": Explanations in mathematical problem solving*. A paper presented at the Annual Meeting of the Canadian Society for the Study of Education, Calgary.

STEINER, M. (1978). Mathematical explanation, *Philosophical Studies*, **34**, 135–151.

Science

The role of mathematics and physics in engineering degrees

Arif S. Al-Hammadi and R. H. Milne

Etisalat University College, Sharjah, United Arab Emirates

One of the most important strategic aims for effective learning is production of the most suitable syllabus. It is widely accepted that a knowledge and understanding of mathematics and physics is required for engineering. However, engineers are becoming more specialised, and in the later stages of engineering degrees, the direct reliance on mathematics and physics is replaced by specific knowledge of the higher-level processes (and less on the underlying principles). In this paper the role of mathematics and physics within engineering degree courses provided by Etisalat University College in Sharjah, United Arab Emirates is considered. Perceptions of the knowledge required, obtained by analyses of questionnaires given to staff and students, is presented. Specific information on the role of mathematics and physics is obtained by analysing students' results in these subjects with their overall degree result. This information is obtained using neuro-fuzzy techniques. Implications for incorporating the appropriate balance between knowledge of the underlying principles and state-of-the-art engineering methods in degree programmes are presented.

Introduction

It is currently accepted that undergraduate engineering students need a solid understanding of mathematics and physics. This can be seen by examining syllabi of engineering degrees from around the world and is reinforced by the requirements of accreditation bodies. As engineering continues to expand rapidly and becomes more sophisticated, it is important to establish which mathematics and physics topics need to be included in engineering degrees, and the depth of this coverage. To a practicing engineer working in a specialised area, any required mathematics and physics can now often be obtained from 'plug and play' software. In terms of Bloom's taxonomy (Bloom, 1956), the working engineer deals with the higher categories, namely application, analysis, synthesis and evaluation whereas physics and mathematics to the working engineer are primarily linked to the first two categories of knowledge and comprehension.

Little research seems to have been produced on the coverage of physics and mathematics within engineering degrees. For example, a ‘Special section on a vision for ECE education in 2013 and beyond’ in the *IEEE Transactions on Education* (Various authors, 2003) has several papers mentioning the amount of science and mathematics content envisioned, but they do not consider the individual topics to be covered. As an example, ABET[1] accreditation criteria for electrical and computer engineering (ABET, 2005) are not prescriptive about the physics content, but do specify probability and statistics, calculus, differential equations, linear algebra, complex variables and discrete mathematics.

In order to investigate the mathematics and physics topics which should be included in the engineering syllabi at Etisalat College of Engineering, United Arab Emirates (UAE), two approaches were taken. First, questionnaires were distributed to both students and staff to elicit their views. Second, an analysis was performed to determine actual connections between students’ performance in their mathematics and physics courses with their final engineering degree result. Etisalat College runs three undergraduate degree courses, Electronic, Computer, and Communication Engineering, all of which are accredited by the Ministry of Education in the UAE and with the Institute of Electronic Engineers (IEE) in the UK.

Questionnaires on physics

Approximately fifty final year students and twenty-five Engineering lecturers were given questionnaires. They were asked to rate thirty-four physics topics in terms of their importance to students becoming professional engineers who have taken degrees similar to the one being taught/lectured. The possible ratings were:

0. Not important at all.
1. Students should have a basic awareness of the topic.
2. Students should be reasonably familiar with the topic.
3. Students should have a good understanding of the topic.

The topics were basically the chapter headings found in most popular American ‘Physics for Engineers’ texts. The order of the topics was taken from one book so that there is a logical progression through the major areas: Mechanics, [topic numbers 1-11], Electromagnetic waves [12], Thermodynamics [13-16], Electricity and Magnetism [17-26], Optics [27-28], and Modern Physics [29-34]. Some of these topics are not covered in the Etisalat College syllabi, e.g., Relativity [29]. The results were analysed in six different groups using staff and students from each degree course. Figure 1 shows the results from the three sets of faculty. The first notable result is the general similarity in ratings from the three departments both from topic to topic and in the average rating;

[1] Accreditation Board for Engineering and Technology, based in the US.

electronic staff 2.1, computer staff 2.1, communication staff 1.9. There are obviously some differences, e.g., the electronic group rated electrical and magnetic topics higher but these are comparatively small. The second point is that all topics (with the exception of 'Quarks, Leptons and the Big Bang' [34]) received a rating of at least 'basic awareness'. The results from the three groups of students (see Figure 2) show a similar uniformity between the groups. There is basic agreement about the importance of different topics and the overall averages are similar: electronic students 1.8, computer students 1.6, and communication students 1.7. A comparison of the average student ratings and the faculty ratings is shown in Figure 3. There is general agreement over the most relevant topics, although the overall student perception of the importance of individual topics tends to be lower than the faculty's perception.

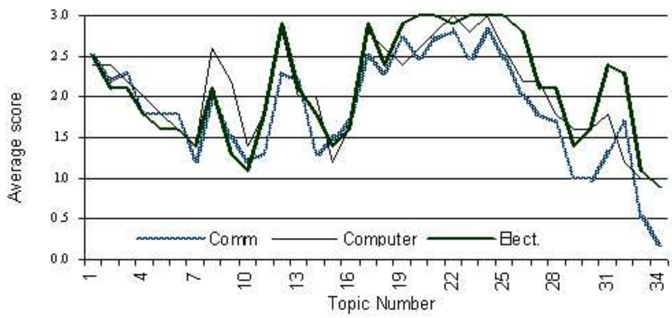


Figure 1: The perceptions of staff from the three departments on the relevance of physics topics.

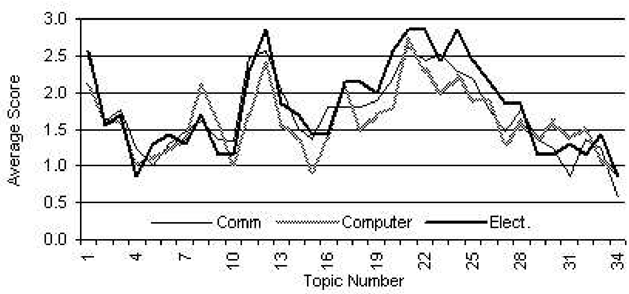


Figure 2: The perceptions of students from the three departments on the relevance of physics topics.

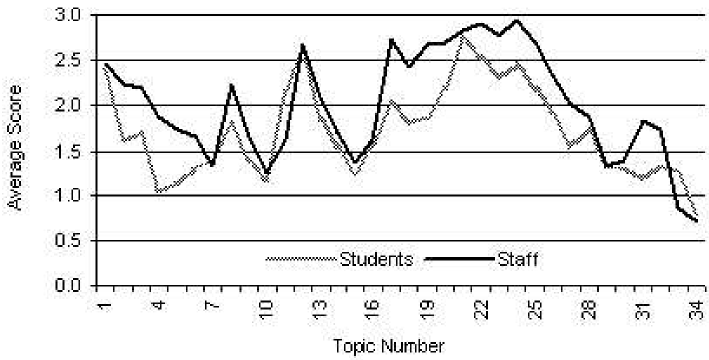


Figure 3: Comparison of student and staff perceptions on the relevance of physics topics.

Questionnaires on mathematics

A similar form of questionnaire was set for mathematical topics. The twenty-eight topic titles were selected by one of the College's mathematics lecturers to include topics covered in the current syllabus and other potentially useful areas of mathematics. These topics were: Basic Mathematics [1], Basic Algebra [2], Calculus [3], Multivariate Calculus [4], Linear Algebra [5], Numerical Analysis [6], Numerical Methods [7], Real Analysis [8], Complex Analysis [9], Vector and Tensor Analysis [10], Engineering Mathematics Topics (e.g., Fourier, Laplace, etc.) [11], Probability and Statistics [12], Discrete Mathematics [13], Finite Mathematics [14], Finite Element Method [15], Boundary Element Method [16], Finite Volume Method [17], Calculus of Variations [18], Differential Equations (including Partial Differential Equations) [19], Optimisation [20], Classical Mechanics [21], Continuum Mechanics [22], Wavelets [23], Logic [24], Predicate Calculus [25], Pure Mathematics Topics [26], Functional Analysis [27], Homogenisation Method [28]. Again, the questionnaires were filled in by final year students and engineering faculty. The responses from the staff and the students are similar with the staff being slightly more dogmatic with their ratings (see Figure 4). The main difference in results were observed between departments where the computer staff and students rated some of the topics (numerical analysis to vector and tensor analysis) lower compared to the other two departments (see Figure 5).

Physics, mathematics and final degree results

The use of a neuro-fuzzy (NF) program to compare students' school and college entry tests with their final graduation mark has been reported previously, along with the

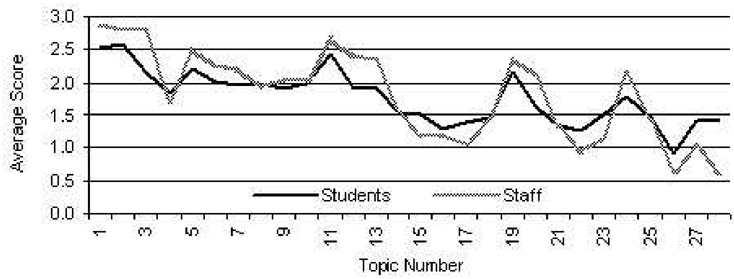


Figure 4: Comparison of student and staff perceptions on the relevance of mathematics topics.

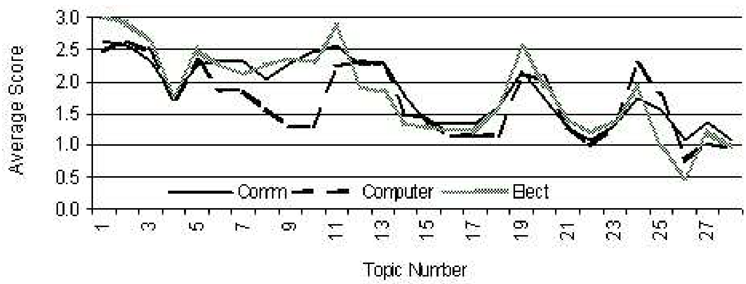


Figure 5: Combined staff and student perceptions on the relevance of mathematics topics from each department.

technical details (Al-Hammadi and Milne, 2003, and references therein). Here a similar method was employed to find connections between students' abilities in mathematics and physics with their engineering abilities as shown from their college marks. Specifically, first year semester one and two marks were compared with a student's marks at graduation.

Neural networks are used in solving problems where the system has to learn or adapt to the various inputs to give the required outputs. Fuzzy logic is often used to tackle problems that are inherently vague or imprecise. Here a combination of both methods, namely a NF system, is employed. This allows rules relating the students' early marks with their graduation results to be generated despite the natural variation in performance that will be present within a cohort of students over five years.

For this study the input into the NF system were the individual student results for

mathematics, physics, introductory computing, and English for the first two semesters. Each of these results were categorised on a scale of 0–4. The outputs were the graduation marks categorised on a scale of 0–6. The NF system analyses the information and generates a set of rules that predicts a student's graduation performance from the first year results. In order to quantify the importance of the individual input categories in determining the output level, the rules predicting the top two and the bottom two output levels were compared. This is achieved by summing the numbers from each input (e.g., for mathematics, first semester) for each rule that predicted top results and subtracting the sum obtained from the rules predicting the lowest results. The resulting number is an indication of the strength of the relevance of a top first year result in a particular subject to finally achieving a top graduation mark. These calculated numbers are shown in Table 1. It can be seen that the strongest requirement for obtaining a top graduation mark is a good mathematics mark followed by physics. Introductory computer studies had very little influence and the first semester English total (-11) shows that potentially good engineers can overcome weakness in English. It is interesting to note that all the second semester numbers are higher than the equivalent first semester numbers. This indicates that the students' academic achievements at the end of the second semester are a better predictor of graduation results than those from the first semester.

	Mathematics	Physics	Computer	English
First semester	15	6	0	−11
Second semester	34	11	3	2

Table 1: Strength of the connection between first year subject marks and achievement of top graduation mark.

Discussion and conclusion

The design of engineering syllabi for undergraduate degrees currently recognises the importance of mathematics and physics. However, the spread and depth of topics covered has primarily been determined by the time available and the perceptions of the academic staff involved in devising the curriculum. Although each institution will have its own criteria, this paper gives several pointers to issues that should be considered. The conclusions of this paper are not based solely on staff perceptions but also on the outcomes from the student learning process.

The NF study shows the importance of students having a good grounding in mathematics and physics and also clearly shows that in terms of obtaining a good graduation mark, the mathematical ability of the students was more important than their knowledge of physics. This supports the conclusions of the paper by Al- Hammadi and Milne (2003) where College entry tests were compared with graduation results.

The questionnaires concerning student and staff perceptions on the requirements of mathematics and physics for engineers showed a strong similarity between both groups and between different specialties (within the electronic, communications, and computer areas). Although particularly relevant topic areas were identified, there was a general appreciation that a wide range of topics should be introduced rather than tailoring syllabi too closely to the requirements of the particular degree course. This makes sense from the pedagogical viewpoint; engineering is a rapidly changing profession and new graduates should be equipped to understand changes in technology which will occur throughout their careers. The ability to comprehend these changes will often be based on having a certain familiarity with the physics underpinning the new techniques and equipment being introduced. In general, the results show that Bloom's taxonomy should be taken as pyramidal, with the earlier stages (including mathematics and physics) having a broader scope than the more advanced and specialised engineering topics.

References

ABET (2005). *Criteria for accrediting engineering programs* [online]. Available from: `http://www.abet.org`

AL-HAMMADI, A.S. AND MILNE, R.H. (2003). A neuro-fuzzy approach for student performance modelling, in *Proceedings of IEEE International Conference on Electronics, Circuits and Systems* (Vol. 3, pp. 1078–1081). ICECS'03.

BLOOM, B.S. (1956). *Taxonomy of educational objectives*. Longman: White Plains, NY.

VARIOUS AUTHORS (2003). A Vision for ECE education in 2013 and beyond, *IEEE Transactions on Education*, **46**(4), 405–476.

Burning in a closed environment: Science teachers' conceptions

Harkirat S. Dhindsa

Department of Science and Mathematics Education, Universiti Brunei Darussalam, Gadong, Brunei

Subject content knowledge and confidence in it are vital for teaching science effectively to students. Teachers often claim to know the subject content confidently, but they lack the understanding required to apply many pieces of information to solving a problem. This study evaluated sixty working and twenty pre-service secondary science teachers' conceptions of burning in a closed environment and their confidence in the accuracy of their conceptions. They were asked to think of the experiment: a candle burning in an inverted jar over water in a trough. All these teachers have performed this experiment many times during their teaching. Multiple-choice questions and interviews were used to collect data. The multiple-choice questions also asked them to record their confidence that their responses were correct. The teachers were shown to have little understanding about this experiment, but they were highly confident that their conceptions were correct. For example, they did not think of the minimum level of oxygen required for burning and the solubility rate of carbon dioxide in water while responding to the questions. It appears that conceptual knowledge stored in a teacher's brain is not properly connected, therefore he/she is unable to pool it together effectively to solve simple problems as described in this experiment. The study also discussed some simple experiments that could help teachers to correct their misconceptions and improve the connectivity of concepts in their brains for effective teaching. Teachers in schools and teacher educators in teacher training institutions should target teaching for understanding. More research on how to make teachers more flexible in thinking and in pooling their information to solve simple problems confidently and accurately is recommended.

Introduction

According to the Nobel Laureate Rabindra Nath Tagore, teachers can never truly teach unless they are still learning as well. It has been reported from different countries that many secondary school students', adults', and teachers' conceptions of science concepts differ from the accepted measure (Dhindsa, 2000; Kesidou and Duit, 1993; Lewis and Linn 1994). More specifically, Bruneian studies have suggested that pre-service teachers as well as school teachers have inadequate science content knowledge (Dhindsa, 2000; Tan, 1995; Yong 2000). The impact of this level of understanding of content knowledge in prospective and working teachers on future students is of real concern.

Constructivist theory highlights (a) the role of prior conceptions and knowledge structures in the process of science learning (Anderson, 1992; Bodner, 1986; Novak, 1977), and (b) the role of active learning and plasticity of thinking in construction of knowledge through learners' mental and physical involvement (Ausubel, Novak and Hanesian, 1978; Bolton, 1977; Bruner, Goodnow and Austin, 1965; Mitchell and Lawson, 1988). Constructivist teaching is a process of helping students mobilise their prior understandings and reorganise them in light of current experience. In practice, this may involve, among other approaches, small group discussions to foster contrasting ideas, encourage reflection on experimental data, and motivate a re-evaluation of prior ideas in relation to emerging evidence. This is an active construction of new knowledge. It can be enhanced or hindered by the students' and teachers' conceptions and organisation of extant knowledge structures. During information construction, the teacher helps students to interpret new experiences actively based on stored information (Anderson, 1992). Therefore, in the process of encoding new information, previous knowledge structures will be (a) partly supplemented or broadened (conceptual growth), or (b) rearranged and newly structured (conceptual change). In the process, the range of knowledge applications and the richness of network connections in memory and their linkages to sensory input are often enhanced (e.g., Duit, 1994). However, a major concern is if the teacher's conceptual knowledge is not acceptable (wrong) yet the teacher remains confident in its correctness.

Research in the area of student confidence in their knowledge revealed that a student's confidence in his/her responses to the content questions varies greatly (Lundeberg, Fox and Puncochair, 1994; Monaliza, 2001). These studies support that a student's prior knowledge could be classified into two categories based on what students know with and without confidence. Using these two modes of classification of students' prior knowledge, four categories of knowledge could be obtained. Category 1: students perceive the knowledge as scientifically acceptable (correct) and it is acceptable, category 2: students perceive the knowledge as scientifically unacceptable (incorrect) but it is acceptable, category 3: students perceive the knowledge as scientifically acceptable but it is unacceptable, and category 4: students perceive the knowledge as scientifically unacceptable and it is unacceptable. Shimomura, Oda and Senda (1982) analysed stu-

dents' prior knowledge and confidence in it, using mathematics content, and interpreted category 1 as reliable understanding, category 2 as unreliable understanding, category 3 as misunderstanding, and category 4 as no understanding. This classification is also applicable to teachers' knowledge. The interactions between four types of knowledge from teachers and from students could be chaotic. Category 4 is very limited and generally is not involved in the construction of knowledge. Teachers teach category 1 and 3 knowledge confidently, and their students use prior knowledge representing categories 1 and 3 effectively for the construction of new knowledge. Category 1 favours construction of scientifically acceptable knowledge, whereas category 3 hinders the construction of scientifically acceptable knowledge if it leads to misconceptions and confusions. Assuming that a teacher's knowledge is acceptable and the teacher teaches it confidently, the learners might use category 2 prior knowledge to construct scientifically correct new knowledge without much confidence in its accuracy, whereas, they might use category 3 prior knowledge to construct scientifically incorrect knowledge, with a false confidence in its accuracy. However, learners use category 1 more effectively than category 2 during the construction of new knowledge because of confidence differences in the two categories. This argument is based on a discussion reported by Dhindsa and Wimmer (2003).

Identification of the preconceptions, however, precedes correction. Although various methods, including objective type tests, interviews, and flow maps for identifying students' preconceptions have been proposed, all these methods have limitations (Anderson and Demetrius, 1993; Bar and Galili, 1994; Lee, Eichinger, Anderson, and Berkheimer, 1993; Wenzel and Roth, 1998). A major problem with objective types of tests and interviews in identifying preconceptions is that the questions in them direct the students' thinking towards the examiner's point of view. The others are time consuming and are labour intensive and therefore not very efficient when it comes to collecting data from large samples. Recent developments show that the students' own statements, rather than expert guided statements, should be used to evaluate students' points of views (Aikenhead and Ryan, 1992). Schmidt (1991) used multiple-choice questions (MCQ) and asked the students to describe reason(s) for their decision. This method is still efficient and is a preferred way of collecting large quantities of data quickly, though its limitation is in language. Students with language deficiencies often cannot explain their logic in making a decision. Conceptual understanding mapping (Doig, 1995) and Structure of Observed Learning Outcome (SOLO) Taxonomy (Levins 1997) methods have been used to analyse students' preconceptions. However, in this study the number of respondents was relatively small, and in-depth exploration of understanding was required, therefore MCQ and interview data were used to triangulate the results.

Analysis of ERIC and other related data bases revealed a few studies on conceptions of primary and lower secondary students of combustion have been reported during the second half of last century (BouJaoude, 1991; Meheut, Saltiel and Tiberghiem, 1985). These studies show that students believe that oxygen is finished by the candle burning in the jar and water rushes into the jar to take up empty space created as oxy-

gen is consumed during burning. However, it appears that very little attention has been paid to teachers' conceptions of this concept. Moreover, much less is known about teachers' confidence in the correctness of their conceptions. Furthermore, most of the studies conducted in teachers' understanding of the scientific concepts are centred on the theoretical concepts (Dhindsa, 2002; Yong 2000), however, understanding practical application of theoretical knowledge also needs further attention. In this study, teachers' understanding of burning in a closed environment and their confidence in their conceptions to be correct were investigated using the candle burning in an inverted jar over water in a trough experiment.

Method

Sample

The subjects of the study were sixty science teachers teaching in Government schools in Brunei and twenty pre-service teachers studying in the final year of their degree programme. All the teachers were trained. The majority of them had an undergraduate degree, but some only had diploma qualifications. The number of females was about double that of males. Their teaching experience at secondary schools varied from three to ten years.

Instrument and procedure

The instrument used in this study consisted of seven MCQ. The seventh question was linked to question 6. Depending upon the response to question 6, the respondent was asked to respond to 7a or 7 b. Question 7a was a multiple-choice question, whereas 7b required a written description of why they chose their specific choice, that is 'water rises to equal levels in all three jars'. A description of the questions is reported in the paragraph below. Teachers' confidence in their response scale was embedded in the MCQ. A sample question from the questionnaire used is given in Figure 1. Participation was voluntary. The instrument was given to teachers in their staffroom and to pre-service teachers in their classes. The MCQ items were based on information in Figures 2 and 3.

There were four questions based on information given in Figure 2. The first question asked concerned the reaction taking place in the jar, the second, why the candle goes out after some time, the third, why the water moves into the jar, and the fourth, if hot air escaped from the jar before it touched the water. The expected answer to the first question was: hydrocarbon reacting with oxygen to produce carbon dioxide and water (easy question), and to the second: oxygen is reduced in the jar. The third question investigated common misconceptions that are: (i) all oxygen is used up, or (ii) carbon dioxide is dissolved in water, and the answer was that air escaped during the process of placing the jar on the candle. In the third question it was expected that the respondents would respond with all the oxygen being used or carbon dioxide is dissolved, and this occurred. The fourth question expected them to concentrate on thermal expansion and expected them to answer that water moves in the jar to compensate for a decrease in

Instrument	
Test item	Confidence item
Q5. What would you estimate about the time before the candle(s) in Figure 3 goes out?	I'm certain I'm right.
	I think I'm right.
A. Candles in x, y and z will go out at the same time.	I think I'm wrong.
B. Candle in x will be the last to go out.	
C. Candle in y will be the last to go out.	I'm certain I'm wrong.
D. Candle in z will be the last to go out.	

Figure 1: Sample of one of the multiple-choice questions used together with its embedded confidence scale.

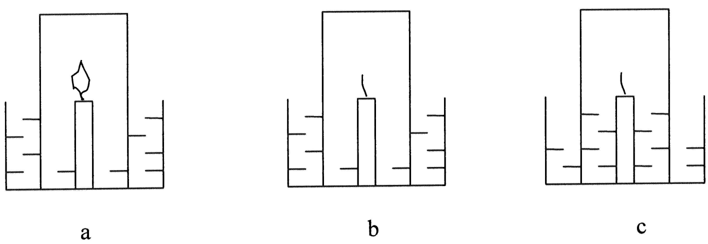


Figure 2: Three experimental stages: A candle burning in an inverted jar over water in a trough.

air pressure after cooling as some air escaped from the jar due to thermal expansion during the process of placing the jar on the candle.

Questions four to seven were based on information given in Figure 3. Question 5 asked in which jar the candle(s) will go out last (easy question) and the expected answer was x. Question 6 asked in which jar (x, y, or z) the water would rise highest? The fourth choice for this question was equal level in all three. The expected answer was z because more air escaped from the jar in the beginning due to a larger amount of heat being released by the three candles. Question 7 asked them to give a reason for their choice in question 6. If they chose x or y or z they were asked to respond multiple-choice question 7a, if they chose equal level in all jars for question 6, they were then asked for a written description as to why they thought so? Questions 1 and 5 were considered easy questions as more than 90% of responses were correct. The other questions were treated as difficult since the percentage of correct responses were considerably less: in the range of 10% to 27%. The responses to easy and difficult

questions are discussed separately.

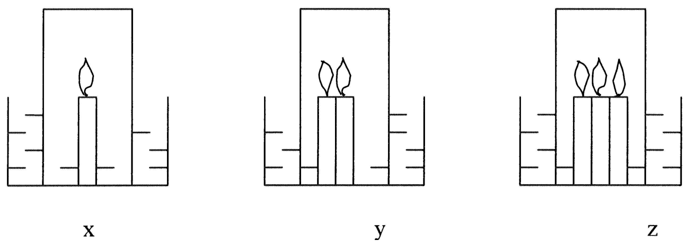


Figure 3: Three experimental conditions: A candle burning in an inverted jar over water in a trough.

What is happening in this experiment?
When we ignite the candle, the hydrocarbon reacts with oxygen (in excess) to produce carbon dioxide and water. The burning sets up an air current which produces a dome shape to the candle flame and helps to complete combustion at the bottom and the outer surface of the flame. The hot air and products of combustion rise up above the flame. As soon as the gas jar comes over the flame, the hot gases moving upward enter the jar, the air inside the jar expands and causes some of the air to be pushed out of the jar. This process goes unnoticed. As soon as the jar touches the water, the burning occurs in a closed environment. Further pressing of the jar into the water helps retain the air in the jar, which is less in quantity than at room temperature and pressure. However, due to thermal expansion, the pressure is higher than atmospheric pressure which is balanced by pressure, from the water. The burning of hydrocarbon in the jar produces about 30% more molecules of carbon dioxide and water than the molecules of oxygen consumed in the reaction (see below for the expected chemical reaction). The increased heat and number of molecules increases the pressure inside and as a result, if one is not careful, some bubbles of gas will escape from the jar. Over time the oxygen in the jar is reduced and conditions for burning are changed. Burning under reduced oxygen may not produce carbon dioxide, rather carbon monoxide (very little). When the candle is put out, the temperature decreases and is followed by a corresponding decrease in pressure due to condensation of water vapour, and a decreased quantity of air due to thermal expansion during the process of placing the jar on the candle. The overall situation is a decrease in pressure inside the jar compared to atmospheric pressure. Therefore, despite water being heavier than air, air is pulled into the jar. How much does the water level rise as a result of dissolving carbon dioxide? Very little, practically negligible, during 30–40 minutes, the time the experiment usually takes to perform in a classroom situation.

If the number of candles is increased in the jar, the heat produced is more, therefore

more air is likely to escape from the jar due to thermal expansion during the process of placing the jar over them. Accordingly, more water will rise in the jar with more candles.

Expected chemical reaction

The nature and quantity of the products will depend upon the composition of the candle material. However, it is assumed that combustion of saturated hydrocarbons is taking place during burning.

$$\mathrm{C}_n\mathrm{H}_{2n+2}(\mathrm{s}) + (1.5n + 0.5)\mathrm{O}_2(\mathrm{g}) \longrightarrow n\mathrm{CO}_2(\mathrm{g}) + (n+1)\mathrm{H}_2\mathrm{O}(\mathrm{g})$$

For $n = 1$, two moles of oxygen will react with a mole of CH_4 to produce three moles of product molecules. The number of moles of the product molecules is 1.50 times that of oxygen. As n increases, the multiple factor decreases from 1.50 and approaches 1.0 as $n \to \infty$. For $n = 30$ (a typical paraffin wax), the factor will be 1.34.

The overall understanding of the experiment is that all the oxygen is not used up (I have tested for the presence of oxygen after the candle has been put out in our laboratory using yellow phosphorus) and the consumption of oxygen does not create empty space, rather the number of product molecules in the jar increases over that of the consumed oxygen, thus giving rise to an increase in overall pressure in the jar (see the above chemical equation). Moreover, an almost equal number of molecules of carbon dioxide and water are produced. A quick rise in water in the jar after the candle is extinguished is mainly due to a decrease in pressure as a result of a decrease in the amount of air in the jar. This decrease results from thermal expansion on placing the jar on the candles and bubbles escaping (if any) through the water, and possibly the condensation of some water vapour. The amount of condensation of water will depend upon the temperature difference between the initial and final temperatures of the air in the jar. Since the air is above the water, a saturated water vapour pressure is considered in the beginning of the experiment. Increases in temperature, during the candle burning, will make air unsaturated to accommodate additional water vapour, especially that produced as a product of burning. A decrease in temperature over time, after the candle is extinguished, to the initial temperature will help water vapour to condense. This condensation will decrease the pressure inside the jar and will help the water to rise in the jar. A small amount of water vapour usually condenses during a small change in temperature but may be too small to notice. The amount of carbon dioxide dissolved in water is minimal in the 30–40 minutes during which the experiment is conducted.

Results

The results of the study are reported under the following heading: (i) summary of responses to individual questions, (ii) comparison of responses to easy and difficult questions, and (iii) interview results. In the following paragraph, CR is a correct response,

IR is an incorrect response while CC is certainly confident. The reported CC data is for the percentage for reported CR or IR.

Summary of responses to questions considered individually

The analysis of respondents' data on the seven questions revealed that teachers knew what reaction was occurring in the jar (CR=98.7%; CC= 51.8%). They confidently believed that all the oxygen was consumed during combustion before the candle was extinguished (IR=75%; CC = 60%) and the water rose in the jar to fill the vacuum created by the consumption of oxygen (IR=90%; CC 53.8%). They did not expect the air to escape from the jar as a result of thermal expansion (IR=73.1%; CC= 29.5%). They believed that one candle would burn longer in the jar than three candles (CR=91.1%; CC=57.0%). Most of them reported that the water level in the jars with different candles would rise to the same level as the amount of oxygen in the jars to start with is the same (IR=78.2%; CC=50%). These results are supported by interview data. The quantitative and qualitative results show that teachers had a limited level of understanding of the experiment.

Questions		Response		% Confidence			
No.	Type	Type	%	CC	TC	TW	CW
1	All	Correct	41.9	19.5	20.8	1.6	0.0
		Wrong	58.1	33.5	21.5	2.7	0.4
2	Easy	Correct	94.9	54.2	39.1	1.6	0.0
		Wrong	5.1	3.2	1.9	0.0	0.0
3	Difficult	Correct	20.7	5.6	13.4	1.7	0.0
		Wrong	79.3	45.7	29.3	3.8	0.5

Table 1: Respondents' responses to questions and confidence in their responses being correct.

Comparison of responses to easy and difficult questions

The results in Table 1 (see data for All) show that 41.9% of the responses were correct and the remaining 58.1% incorrect. Of the 41.9%, 19.5% of the responses were certainly confident in the accuracy of their responses, whereas 20.8% were doubtful to some extent. On the other hand, 33.5% of respondents were certainly confident that their wrong responses were correct and 21.5% thought that their responses were correct. Even for easy questions, only 54.4% were certain of the accuracy of their response, whereas 39.2% thought their responses were correct. For difficult questions, 45.7% of the respondents were confident that their wrong responses were correct. It is surprising, that despite the large proportion of wrong responses, teachers did not know that they were wrong.

Interview Results

Interviews with four trained graduate science teachers were conducted. These teachers

were teaching 14–16 year old pupils. During the interviews, the teachers were asked the reasons for selecting their response to each of the questions in the MCQ questionnaire. They were also asked additional questions dealing with prior knowledge that was believed to be important for answering the questions. The interview data supported the above results. As a sample, an interview with a Form 4 teacher is reported in Table 2.

Question No.	Teachers' answer to MCQ	Interview response
1	b. Oxygen is reacting with carbon.	Air contains oxygen and carbon is present in the wick and in the wax. Carbon reacts with oxygen during the burning.
2	a. Oxygen is finished in the gas jar.	It is because for burning or combustion, oxygen is used up. So normally the candle goes out and the percentage of oxygen is exhausted or finished.
3	a. To take up empty space created by finished oxygen.	When the combustion is over, oxygen is used. This creates a space inside the gas jar and water moves in to take the space. In the gas jar, the amount of oxygen is all used.
4	b. You disagree because there was no hot air in the jar.	Before lighting the candle, the air inside is normally at atmospheric pressure and at normal room temperature. So, there is no hot air before lighting. It stays in the gas jar as hot air rises.
5	b. Candle in X will be the last to go out.	This is because there is only one candle and oxygen in the available air is used up. In Y, there are 2 candles and in Z there are 3 candles. The more candles, the faster the rate of combustion.
6	d. Equal in all three.	I am certain I am correct because 20%, or 1/5, of the air in the gas jar is oxygen. It is the same for all three gas jars so the level is the same in all three no matter what the number of candles.
7	b. The level of oxygen (% of) is same in all the three jars.	The level of oxygen is the same in all three jars.

Table 2: Explanation of questionnaire answers through interview.

Interview responses to additional prior knowledge questions

During interviews, some additional questions were asked to explore teachers' prior knowledge of the processes that can be used to explain the questions asked in this study. The teachers knew that on heating, air expands and increases the pressure in a closed container, whereas in an open container the air escapes from the container by rising away as gases respond to heat faster than liquids and solids. They had observed air bubbles escaping from the jar through water. They knew that in a chemical reaction, atoms and molecules combine in a fixed whole number ratio and a chemical equation indicates the molar ratio between reactant and products. They also knew that the bigger the flame, the more heat and gaseous products being formed during burning. However, many of them did not recognise that during hydrocarbon burning, the product gaseous molecules would be more than that of the reactants.

The responses of male and female teachers to easy and difficult question and their confidence in the responses to be correct are reported in Table 3. While discussing the results it was assumed that a 10% difference is educationally valuable. It is clear from the data in Table 3 that female teachers' responses were significantly more correct than those of the male teachers. There was no difference in the responses to easy questions, however, this difference has appeared in responses to difficult questions. The data also suggest that male teachers were certainly more confident in their wrong responses to be correct by 8–9% than female teachers. The male and female teachers were equally unaware of knowing when they were wrong. In general, the degree of certainty in male and female respondents' responses being correct was lower than their certainty in their incorrect responses being correct.

		Correct answer to MCQ					Wrong answer to MCQ				
QT	Sex	MCQ	CC	TC	TW	CW	MCQ	CC	TC	TW	CW
All	M	34.6	17.1	17.5	0.0	0.0	65.4	37.5	25.9	1.5	0.5
	F	45.6	22.8	22.8	0.0	0.0	53.4	30.2	19.3	3.6	0.3
ESY	M	96.3	54.6	41.7	0.0	0.0	3.7	1.9	1.8	0.0	0.0
	F	94.2	52.7	41.5	0.0	0.0	5.8	3.5	2.3	0.0	0.0
DIF	M	10.0	2.1	7.9	0.0	0.0	90.0	50.7	36.6	2.1	0.6
	F	27.1	11.1	15.1	0.9	0.0	72.9	41.5	26.4	5.0	0.0

QT = questions set type; ESY = easy; DIF = difficult; MCQ = multiple choice question; CC = certainly correct; TC = think correct; TW = think wrong; CW = certainly wrong.

Table 3: MCQ and confidence scale responses (%) of male and female respondents in correct and wrong answers.

Discussion

The teachers were not confident in their correct knowledge and were confident in incorrect responses. These teachers will teach correct knowledge with less confidence and incorrect knowledge with more confidence. Using the theory of constructivism, the interaction between the incorrect knowledge of teachers taught confidently and the correct prior knowledge of students will produce the construction of incorrect knowledge (Dhindsa and Wimmer, 2003). As discussed in the introduction, there are four types of knowledge of teachers and also of students. The probability of interactions between the correct knowledge of teachers and of students is low and it depends upon the extent of the correct knowledge of teachers and prior knowledge of students. More interestingly, despite teachers giving wrong responses they did not report that they were certain of being wrong. It may mean that we are not trained to know when we are wrong. It is important that future teachers are trained to know when they are and are not wrong.

Teachers during the interview agreed that they had seen air bubbles escaping through the water from the jar. However, they did not use this knowledge to explain the rise of water in the jar. It appears that teachers treat this observation as a minor detail of the experiment and therefore ignore it. It is therefore important that while training teachers or teaching students, the observation of micro along with macro processes/points and their use in explaining the major question needs to be encouraged.

The prior knowledge questions asked of teachers during interview revealed that they had sufficient prior knowledge to answer the questions asked confidently, however they did not use this knowledge at all. One of the possibilities is that the knowledge in the teachers' minds was very weakly connected and although it was there, it was not accessible for the solving of simple problems like the one discussed in this study. This is because teachers store various pieces of knowledge in isolation, in the same way that we store all the apparatus for an experiment in a tray. Any piece of apparatus that is not in the tray will not be used. Therefore, they take each piece of knowledge as an individual entity. Can we help teachers improve connectivity in the extant knowledge? Dhindsa and Andserson (2004) proposed that flexibility in thinking and interconnectedness of conceptual knowledge can be increased by conducting short-term in-service training using cognitive strategy instruction programmes, delivered using a conceptual-change approach.

The major implication of this research is that students at schools as well as at institutions of higher education should be taught for understanding rather than for memorisation. Moreover, techniques for connecting information should be stressed to improve links between different pieces of knowledge. Replacement of teacher guided experiments with project work should help. Teachers should try different experiments to help them improve their conceptions. They should explore multiple sources to confirm the correctness of their knowledge. In this light, we have performed some experiments to help our teacher trainees to change their conceptions. These include studying the solubility rate of carbon dioxide by inverting a jar full of carbon dioxide over water,

studying the level of rise in the water when the candle is put out as soon as it is covered, studying the presence of oxygen in the jar after the candle is put out by using white phosphorus, pyrogallol, iron-wool, insects and nitric oxide gas, and testing if the carbon dioxide removed from human breath helps the candle to keep burning. The students enjoyed these experiments. They also found these experiments helpful in making them think logically to understand the overall process of burning.

Conclusion

Teachers, despite knowing all the information required to answer the questions correctly, were unable to access and utilise their stored knowledge to solve simple problems. The inability to do so appears to put them in a state where they are either not confident in their correct knowledge or they are confident in the incorrect knowledge being correct. Using their incorrect knowledge confidently to teach their students may result in misconceptions. Teachers should conduct simple experiments to improve their confidence in correct knowledge. More research into ways to improve upon the connectivity of knowledge in teachers' minds is recommended.

References

AIKENHEAD, G. AND RYAN, G. (1992). The development of a new instrument: Views on Science-Technology-Society (VOSTS), *Science Education*, **76**(5), 477–491.

ANDERSON, O. R. (1992). Some interrelationships between constructivist models of learning and current neurobiological theory with implications for science education, *Journal of Research in Science Teaching*, **29**(10), 1037–1058.

ANDERSON, O. R. AND DERMETRIUS, O. J. (1993). A flow-map method of representing cognitive structure based on respondents' narrative using science content, *Journal of Research in Science Teaching*, **30**(8), 953–969.

BAR, V. AND GALILI, I. (1994). States of children's views about evaporation, *International Journal of Science Education*, **16**(2), 157–174.

BODNER, G. M. (1986). Constructivism: A theory of knowledge, *Journal of Chemical Education*, **63**(10), 873–878.

BOLTON, N. (1977). *Concept formation*. Pergamon: Oxford.

BOUJAOUDE, S. B. (1991). A study of the nature of students' understanding about the concept of burning, *Journal of Research in Science Teaching*, **28**(8), 689–704.

BRUNER, J. S., GOODNOW, J. AND AUSTIN, G. A. (1965). *A study of thinking*. John Wiley and Sons: New York.

DHINDSA, H. S. AND ANDERSON, O. R. (2004). Using a conceptual change approach

to help pre-service science teachers reorganise their knowledge structures for constructivist teaching, *Journal of Science Teacher Education*, **15**(1), 63–85.

DHINDSA, H. S. (2002). Pre-service science teachers' conceptions of pH, *Australian Journal of Education Chemistry*, **60**, 19–24.

DHINDSA, H. S. (2000). Using students' pre-conceptions for teaching chemistry concepts meaningfully: An action research project, *Journal of Applied Research in Education*, **4**(1), 38–50.

DHINDSA, H. S. AND WIMMER, F. L. (2004). Students' assessment: Accounting for correctness of and confidence in knowledge, in I. P-A. Cheong, H. S. Dhindsa, A. Kyleve and O. Chigu (Eds), *Globalisation of science, mathematics and technical education* (pp. 40–49). Brunei Darussalam: Gadong.

DOIG, B. (1995). Analysing qualitative data: Simple steps to stunning results, in S. Groves and R. Tyler (Eds), *Contemporary approaches to research in mathematics and science* (pp. 96–104). Deakin University: Deakin.

KESIDOU, S. AND DUIT, R. (1993). Students' conceptions of the second law of thermodynamics: An interpretive study, *Journal of Research in Science Teaching*, **30**(1), 85–106.

LEE, O., EICHINGER, D. C., ANDERSON, C. W. AND BERKHEIMER, G. D. (1993). Changing middle school students' conception of matter and molecules, *Journal of Research in Science Teaching*, **30**(3), 249–270.

LEVINS, L. (1997). Assessment of students' outcomes using a theoretical framework, *Australian Science Teacher Journal*, **43**(1), 56–60.

LEWIS, E. L. AND LINN, M. C. (1994). Heat, energy and temperature concepts of adolescents, adults, and experts: Implications for curricular improvements, *Journal of Research in Science Teaching*, **31**(6), 657–677.

LUNDEBERG, M. A, FOX, P. W. AND PUNCOCHAR, J. (1994). Highly confident but wrong: Gender differences and similarities in confident judgment, *Journal of Educational Psychology*, **86**(1), 111–121.

MEHEUT, M., SALTIEL, E. AND TIBERGHIEM, A. (1985). Pupils' (11–12 year olds) conceptions of combustion, *European Journal of Science Education*, **7**(1), 83–93.

MITCHELL, A. AND LAWSON, A. E. (1988). Predicting genetics achievement in nonmajors college biology, *Journal of Research in Science Teaching*, **25**(1), 23–37.

MONALIZA BTE HJ ABDUL HALIM (2001). *The teaching and learning of heat energy in lower secondary science: A case study*. Unpublished MEd thesis. Universiti Brunei Darussalam: Gadong.

NOVAK, J. D. (1977). An alternative to Piagetian psychology for science and mathe-

matics education, *Science Education*, **61**(4), 453–477.

TAN, B. T. (1998). Pre-service primary teachers' conceptual difficulties with mathematics in physics, *Journal of Applied Research in Education*, **2**(1), 99–104.

WENZEL, M. AND ROTH, W. M. (1998). Do interviews really assess students' knowledge?, *International Journal of Science Education*, **20**(1) 25–44.

YONG, B. C. S. (2000). Science discipline knowledge of teacher trainees in Brunei Darussalam, *Journal of Applied Research in Education*, **4**(1), 26–37.

Some simple physics demonstration experiments

Seán M. Stewart

Department of Physics, The Petroleum Institute, Abu Dhabi, United Arab Emirates

Many principles of physics that make the subject so fascinating can be demonstrated surprisingly easily using simple experiments that make use of nothing more than commonly available materials. In this paper a number of simple demonstration experiments the author has either developed or come across in his years as a teacher of physics are described. In all cases, an appeal to both simplicity of design and the ready availability of materials is made. While a number of old favourites, familiar to most physics teachers, are presented, many other demonstration experiments are described, which it is hoped most will find interesting, new, or intriguing.

Introduction

Physics is an experimental science and as such all its physical principles and laws are firmly rooted in experimental confirmation. The 'development of physical theories ... is always a two-way process that *starts* and *ends* with observations or experiments' (The italics used here are my own. Young and Freedman, 2000, p. 2). Fortunately, as if by design or accident, many of those fundamental principles that underpin the discipline of physics can be demonstrated by simple and direct experiments using nothing more than commonly available materials.

Increasingly, more and more experiences in today's world are lived vicariously in the virtual. Thus, the physical world seems remote and alien for a generation of students weaned on a steady diet of multimedia stimuli. Nowadays, multimedia in the form of television, computers, and the Internet, have become the principal source through which most of our students experience, and come to understand, the world around them. I do not care much for a simulated oscillating pendulum on a computer screen which can no doubt trace out a perfect sinusoidal curve. Instead, one can grab a plastic bottle, fill it with water, connect it to a string and allow it to slowly drain through a small hole in its bottom as one lets it swing to-and-fro while steadily walking along a straight line – and what of the sinusoidal trace one sees on the ground from doing

this! In the study of physics, there is no substitute for experiences and observation of phenomena gained through experimentation.

The foremost purpose of any demonstration experiment is that it allows one to clarify a physical principle, or to show some interesting application of a principle (Sutton, 2003). Here it is important to remember that in a demonstration experiment it is the observation of the phenomena which is more important than the actual accuracy of the result. It is my experience that students benefit greatly from seeing a demonstration of a principle or phenomenon that is under discussion in class. Furthermore, physical concepts tend to become more readily comprehensible to the student when a demonstration experiment can be used for the purpose of clarification compared to when the same concept is presented verbally and/or in mathematical form.

In this paper a number of simple demonstration experiments that readily highlight a number of principles of physics are described. They are taken from topics one typically finds in any standard course on general introductory physics, and are applicable to both upper secondary and lower tertiary level teachers of physics. A theme common to all experiments presented is that they should rely only on commonly available materials for their demonstration. Coupled to this, there should also be a simplicity in design and set-up; the experimental arrangement should be easily and readily understandable and should not unnecessarily obscure the principle one is trying to demonstrate. In all, they represent a collection of the simplest and best demonstration experiments I have come across in my years teaching. Some are no doubt ‘old favourites’ familiar to most physics teachers, while others I hope you find to be interesting, new, or intriguing. In particular, attention is paid to those experiments that have the ability to impress, are novel, or those where the final outcome is either by no means obvious, or at first appears to demonstrate a paradoxical result.

Wherever possible I have tried to attribute each demonstration described that is not my own back to its original creator or inventor. However, as some of the ideas are very old, this is all but an impossible task in some cases. A good and continual source of simple demonstration experiments can be found in *Physics Education*, a journal published six times a year by The Institute of Physics in the UK, or in *The Physics Teacher*, a journal published nine times a year by the American Association of Physics Teachers in the US.

Nice and simple

Each of the first eight experiments highlight how a particular physical principle can be demonstrated with the minimum of fuss. Here confirmation through simplicity is paramount.

Resonance stick

With your hand positioned roughly in the middle, take a very long, thin piece of timber (say 3 to 4 metres) and give it a quick shake before holding your hand steady again so as to observe its natural frequency of vibration. Now vibrate your hand at a frequency

away from the stick's natural frequency of vibration. The stick randomly vibrates with insignificant amplitude. Now force your hand to shake at the natural frequency of vibration of the stick and watch the amplitude of the oscillations at either end grow considerably. As the driving frequency (your hand) matches the natural frequency of vibration of the stick, it is brought into resonance with an accompanying increase in the amplitude of oscillation.

Coat-hanger interference

Fashion two coat-hangers into identical transverse waves (you should be able to get four wavelengths out of a standard coat-hanger). Using a metre stick which has small holes drilled at 10 cm intervals along it, and mounted at either end on blocks, the interference of transverse waves from two point sources can be readily demonstrated. With one end of each coat-hanger positioned into separate small holes along the metre stick, the troughs for each coat-hanger rest out across the bench top. Swinging the coat-hangers around, positions where constructive and destructive interference occurs can be located and the resulting interference pattern developed. In particular, antinodl curves corresponding to a path difference equal to an integer multiple of wavelengths between the two waves can be developed by plotting various points on the antinodal curves onto a large sheet of paper laid out beneath the coat-hangers. A similar thing can also be done for the nodal curves using, say, a different colour to mark out points corresponding on the nodal curve. Changes in the interference pattern resulting from a change in either the separation distance between the two point sources (achieved by positioning of one of the coat-hangers into a new hole along the metre stick) or from a change in the phase, by $180°$, in one of the point sources (achieved by inverting one of the coat-hangers and placing it up-side-down into one of the holes along the metre stick) can also be qualitatively investigated with the apparatus. For further details in the use of this model see Stewart and Neggo (2005).

Water bottle simple harmonic motion

The simple harmonic motion of an oscillating pendulum can be made readily visible. Water (or sand) in a plastic bottle connected to a string is allowed to drain slowly from its bottom through a small hole as it swings to-and-fro. If one then slowly walks along a straight line at a roughly uniform rate, a beautiful sinusoidal curve is traced out by the water on the ground. Doing this on concrete or asphalt gives best results. I first saw this demonstration experiment on the front cover of the February 2004 edition of *The Physics Teacher*. For details see Gabrielson (2004).

PET bottle cloud chamber

A PET[1] bottle which is quarter filled with water has a burning match dropped into it and its lid quickly screwed back on. Initially only a small amount of smoke will be seen in the bottle. However, squeezing the bottle hard and releasing causes the air inside the bottle to become really cloudy (or misty). The sudden drop in pressure inside on releasing the squeezed bottle causes a large number of water molecules to vaporise quickly,

[1]Polyethylene terephthalate.

only to condense again in the surrounding, smokey air. Here the smoke particles act as nucleation centres, and liquid water droplets form around them, forming a visible cloud.

Water tube resonance

A simple way to demonstrate longitudinal standing waves in air using sound is to place a length of pipe (diameter about 2.0 cm) into a one litre measuring cylinder that is completely filled with water so that its end just emerges from the water when fully immersed. As the pipe is raised or lowered, the air column inside the pipe is adjustable as the water at one end forms a closed-end. A vibrating tuning fork, with a frequency of say 512 Hz, is then held close to the open-end of the pipe as it is slowly raised out of the water. An increase in amplitude of the sound should be heard shortly afterwards and corresponds to the fundamental mode of the pipe. It should be possible, depending on the length of tube and frequency of the tuning fork used, to locate the first harmonic by raising the pipe a further distance of twice the height at the fundamental.

Charged propelled aluminium ring

The static charge obtained on a plastic rod (acrylic I have found works best) on rubbing it with silk will attract an uncharged aluminium egg-ring, causing it to roll towards the rod as it is brought near. An empty aluminium soft-drink can could be used in place of the egg-ring. See Freier and Anderson (1996, p. E-7, Ea-15).

Earth inductor

A large rectangular loop of wire, say 1.5 m wide by 4.0 m long, is supported by a piece of timber at either end. The two free ends of the loop are connected to a lecture demonstration galvanometer. With a student at either end holding the loop so that it is in the horizontal plane, they are asked to flip it quickly through 180°. As this is being done, the needle on the galvanometer is observed. Repeat a number of times and also reverse the direction of the rotation. As the loop is rotated it cuts the vertical component of the earth's magnetic field causing a current to be induced in the wire. See Sutton (2003, p. 342, E-222).

Ask and we shall see

The next three demonstration experiments are designed to challenge a student's initial conceptions about some physical principle or concept. Before performing each of these experiments it is best to elicit from the class what they think the final outcome for each might be. Doing so usually tends to initiate much discussion and debate.

Coloured squares

Stick three coloured squares, say blue, pink and yellow, in a row onto a piece of white cardboard. The cardboard is then folded over the row of coloured squares. In good light slightly open the folded cardboard and view the top folded-over section above the coloured squares. Three coloured patches of light immediately above each coloured square of the same colour should readily be seen and results from the reflection of

light off each square. The experiment demonstrates that the colour of an object results from the light it reflects back in the white light spectrum. A common misconception encountered amongst students seems to relate to the mistaken view that as each of the coloured squares does not appear ‘luminous’, how could they possibly ‘give off’ light as it were.

Specular and diffuse reflection

On an overhead projector two sheets of paper are placed side by side so that only a narrow vertical strip of light can be projected onto a nearby flat wall. Due to diffuse reflection, which is scattered reflection from a rough surface, a narrow vertical strip of white light will be observed regardless of the observer’s position within the room. The class is then asked what happens if a plane mirror is placed over the strip of light seen on the wall. Will the light still be seen on the mirror from any position within the classroom? Students are amazed to see that the light reflected from the mirror cannot be seen unless one is exactly in the path of the reflected beam. In diffuse reflection, reflected light in a beam is scattered over a wide range of angles and is clearly demonstrated to be the case from this simple experiment. Hence the light on the wall can be seen from any position within the classroom. On the other hand, in specular reflection, all the reflected light in the beam is reflected at exactly the same angle causing such light to only be seen if you are positioned exactly in the path of the reflected beam.

String pulled on a spindle

With a piece of string wound round and emerging from the underside of a spindle (inner diameter smaller than its outer diameter), the class is asked in which direction it will roll if the string is gently pulled at a number of different angles to the horizontal. Few students if any will correctly guess that the spindle rolls forwards when the string is pulled parallel to the table. The spindle can be made to roll either in or against the direction of the pull, depending on the angle the string makes with the horizontal. Here it is the action of a torque, from the string and the frictional force between the spindle and the table, about the central axis of the spindle which determines the direction it will roll. The experiment illustrates nicely the apparent paradoxical result of a frictional force acting in either the same or the opposite direction to the pull. See Sutton (2003, p. 23, M-24). Also, see Mills, Feteris and Greaves (2005) where the demonstration was given as a ‘challenge’ task to a group of first year university physics students.

Paradoxical or not?

Experiments which appear to demonstrate a paradoxical result are always sure to create a stir amongst your students. There is no better way to make a point regarding some physical principle than by directly challenging a student’s intuition concerning some concept.

Measurement and pi

As a simple measurement experiment, take a wine glass and ask the class (or maybe

your next dinner guests) which is longer; the height of the wine glass or its circumference. More often than not, most people tend to choose the height. Take a piece of string (or your table serviette) and measure the two. To most peoples' astonishment, the circumference of most wine glasses is greater than its height. The error in the judgment of length is a common mistake made by most until one realises that the factor of pi multiplied by the diameter of the glass to give its circumference really is about three times!

Three coin flip

Place a smaller coin (or metal disc) between two larger identical coins, then place this 'sandwich' in one hand and hold it between two of your fingers and your thumb. The class is then asked what will happen when the larger bottom coin is released and falls into your other hand, which is held about 50 centimetres below it. Most students believe the larger coin will land in your hand first with the smaller coin landing on top, in the same order as it was released. Quite unexpectedly, however, it is the exact opposite which actually occurs! The explanation to such an observation comes when one realises it is all but impossible to release both sides of the bottom coin at the same instant. Instead, the side which is released first immediately begins to rotate about its central axis and continues to do so as it falls, thereby causing the smaller coin to fall below the larger coin. The effect can however be negated if the larger coin is given a slight twist on release. The initial twisting now causes the large coin to spin about a vertical axis perpendicular to the surface of the coin. The much smaller torque which is given to the coin from the non-instantaneous release from your fingers now merely causes the coin to precess about its vertical axis. See Edge (1987, p. 1.48.1).

Two springs joined

Two identical helical springs are connected in series by joining their ends using a small piece of string. A mass is then hung from the end of the second. Two additional pieces of strings are then attached to each spring. The first piece joins the top end of the first spring to the top end of the second, while the second joins the bottom end of the first to the bottom end of the second. In both cases, these two additional strings are a little longer than the extended springs and accordingly do not support any of the load. The class is then asked how the total length of the system will change on cutting the central string. Intuitively, most students think the weight will drop downwards, thereby increasing the total length of the system. Such, however, is not the case. Before the string is cut the two springs are in series with each other and each spring bears the entire load of the hanging mass. However, after the central string is cut the springs are in parallel with each other so that each now only bears half the load of the hanging mass. Accordingly, the extension of each spring will be halved. The hanging mass actually moves upwards once the central spring is cut! This little delight originates from Taylor (2002).

Think carefully now

Greater understanding of an idea or concept usually results when one is asked to solve a particular problem or work out an explanation to an observation for oneself. The next two experiments are hands-on demonstrations which require the student to do just that – solve a particular problem.

Build your own torch

In a unit of work on simple dc circuits, after Kirchhoff's rules have been introduced and applied, a 1.5 V D-cell battery, 6 W light bulb and a single piece of wire are given to small groups of students and they are asked to make the bulb glow (i.e., to build a simple torch). I am always amazed at how long it takes them to figure out how this is to be done. The key is to ensure that a closed circuit is built from the three components. To do this, the light bulb is placed on one terminal of the battery while the wire runs from the other terminal of the battery to the metal screw-in base of the bulb. Try this simple experiment with your own students and see how long it takes them to complete the task!

Doherty's 'sprotating' pipe

A white (or light grey) PVC pipe is cut into lengths of three, four and five times its diameter (which is no larger than about 2 cm). Using a black marker, draw at one end a cross while at the other end place a small filled-in circle. With the pipe resting on a smooth horizontal surface and your index finger placed over one end, rapidly push your finger down while at the same time pulling it towards you. The pipe is set spinning and rotating at the same time. Once the motion has stabilised (which does not take long) observe what you see. If a pipe whose length is three times its diameter is used, and if your finger was initially placed over the end marked with a cross, you should see three stationary crosses once the pipe's motion has stabilised. Placing your finger over the filled circle end results in three stationary circles being observed. Pipe lengths of four or five times its diameter result in four or five stationary markings being observed. In order to understand what exactly is going on here, one realises that for the pipe in motion, not only is it rotating about a vertical axis perpendicular to the plane but it is also spinning about its longitudinal axis. As the pipe rotates it forms a blurred circle in the plane, however as it spins, one end of the pipe moves in the same direction as the end of the pipe when viewed from above while the other end moves in the opposite direction to the rotation. The spinning end, which moves in the opposite direction to rotation, therefore actually stops momentarily due to the resultant velocity vectors from the spin and rotation cancelling out. This only occurs if the length of the pipe is an integer multiple of its diameter. For a full mathematical discussion of this fascinating demonstration see Rathjen et al. (2002).

Some fun with slinkies

Slinkies, those long, flexible (non-stiff), helical springs, can be used to perform numerous demonstration experiments, particularly those involving mechanical waves.

Standing waves
To anyone who has ever used a slinky, this is a particular old favourite as it provides beautiful standing wave patterns. Lay a stretched slinky out on a smooth floor. With one end held fixed, the other is vibrated back and forth until a standing wave pattern is set up. By adjusting the frequency at which one vibrates the free end, a number of standing wave patterns, from the fundamental to the fourth or fifth harmonic, can easily be set up. It is also worth having one or two of the nodes of a particular standing wave pattern pointed out by having a student hold a finger from each hand directly over each node.

Fixed and free end reflections
To show that a pulse is inverted on reflection from a fixed end, lay a slinky out on a large bench top and with one end held fixed, send a single, reasonably large-amplituded pulse down the slinky from the free end. The reflected pulse is inverted. To show that a pulse is not inverted from a free end, tie a piece of fishing line of about a metre in length to one end of the slinky. With the end of the fishing line held fixed, the end of the slinky attached to the fishing line behaves as if it is 'almost' a free end. Once more, send a single, reasonably large-amplituded pulse down the slinky from the free end. The reflected pulse will remain upright.

Centre of a falling mass
With an extended vertical slinky hanging under gravity, release one of its ends and watch what happens (releasing from step-ladder height works best). Observe that the bottom of the slinky does not move until the slinky becomes completely contracted and then falls as if it is a single point object. For the falling extended slinky, it is the centre of mass which falls at g. See Gibbs (1999, p. 27).

Fun and games with neodymium 'super' magnets

The strongest permanent magnets that are relatively easy and cheap to come by are neodymium (NdFeB) 'super' magnets.[2] With these little beauties in hand (and be very careful since two of these snapping together can be lethal) many electromagnetic demonstration experiments which require magnetic field strengths of a reasonable size can now be readily performed.

Force on a current-carrying wire
Fashion a piece of copper wire (18 gauge works best) into a 'D' shape with most of the central straight edge part of the dee removed. Here only two smaller straight edge parts remain at either end. Now clip the end of the copper wire between the ends of a D-cell

[2] Available from any good scientific supplier. Try `www.amfmagnetics.com.au` for example.

battery. The dee-shaped wire should be just large enough so that it can swing clear of the side of the battery. The compressive forces within the wire should keep it attached to either end of the battery and a current is now able to flow through the wire. A single neodymium disc magnet is then placed onto the side of the battery. As the casing of the battery is ferromagnetic, the magnet sticks to the side of the battery while at the same time results in a magnetic force to act on the current-carrying wire. The whole arrangement can then be positioned so that the dee-shaped wire levitates from the side of the battery against the force of gravity. See Stewart (2005).

The catenary

A uniform chain (or rope) suspended at either end under gravity takes on the shape of a *catenary* (the hyperbolic cosine function). A particularly nice way I have found to demonstrate this is to take a black chain made from a ferromagnetic material such as steel and hang it against a whiteboard using two neodymium magnets at either end for support (here the black on white gives a nice contrast). The shape of the catenary can then be readily changed by sliding one of the magnets at one end across the whiteboard. A complete mathematical description of the catenary problem can be found in Symon (1960).

Magnetic braking

Part 1: The floating magnet

A simple demonstration experiment students always seem surprised by seeing is another old favourite of mine. Take a neodymium disc magnet and drop one down an aluminium pipe and the other down a plastic pipe. Both pipes are held vertically and are of equal lengths. Before doing so, ask the class through which pipe they think the magnet will travel faster. Most say they will be the same. On dropping the two, the magnet in the plastic pipe drops out in no time at all while that in the aluminium drops out some time later. Here the magnet falling through the aluminium pipe slowly floats down the pipe due to a magnetic force acting on it which results from the eddy currents which are induced in the pipe. According to Lenz's law, the induced currents flow round the pipe in such a direction so as to oppose the motion of the falling magnet providing a dramatic demonstration of what is known as magnetic braking.

Part 2: The rolling magnet

A variation of the floating magnet involves rolling one of the neodymium disc magnets down a piece of aluminium U-channelling which is tilted to the horizontal. Once more, the disc magnet slowly rolls down the U-channelling, again demonstrating the phenomenon of magnetic braking.

Part 3: Feel the force

A kinaesthetic version of magnetic braking is as follows. Using a small wooden or plastic square which fits nicely into one's hand, place a neodymium magnet on either side of this spacer. Holding the square in your hand with one of the magnets facing vertically downwards, gently move your hand just above the surface of a large aluminium or copper surface. As you do this, you should be able to feel a resistive force acting on

your hand each time you pass over the aluminium or copper surface.

Part 4: Damped oscillations
One final way to demonstrate magnetic braking simply is with a neodymium magnet attached to one end of a normal bar magnet, which in turn is attached to a string and is allowed to oscillate just above a large piece of aluminium or copper sheeting. Damping of the oscillations on swinging should be quickly apparent and shows a potential application of magnetic braking in the form of damping away unwanted oscillations without any physical contact between the brake and the oscillating object being made. See Freier and Anderson (1996, p. E-41, El-2).

Suspended aluminium ring
A light aluminium egg-ring supported by two threads connected to a retort stand is hung in the vertical plane. A bar magnet with a neodymium magnet at one end is then quickly moved towards the egg-ring. Repeat, except this time start with the bar magnet inside the egg-ring and draw it quickly away from it. As a result of the process of electromagnetic induction, a current is induced in the egg-ring and causes it to be either repelled by the approaching, or attracted by the receding, bar magnet in accordance with Lenz's law. See either Gibbs (1999, p. 189) or Freier and Anderson (1996, p. E-38, Ek-1).

A simple homopolar motor
The motor consists of four parts: a 1.5 V D-cell battery, one neodymium disc magnet, a non-ferromagnetic piece of stranded wire, and a steel screw which has a flat head. The flat head of the steel screw, being a ferromagnetic material, sticks to the magnet while the point becomes magnetised and allows it to hang as it sticks to the bottom of the ferromagnetic battery casing. Note that the screw needs to be reasonably long (between say 6 to 7 cm) so that it hangs freely under gravity and does not jump up, through attraction, to the base of the battery. Using you hands, hold one end of the wire on the top terminal of the battery and brush the other end against the side of the disc magnet. The magnet is set spinning and is the basic principle behind a homopolar motor. See Chiaverina (2004) for this particular experiment, or Kagan (2005) for a slight variation on a theme.

Wow!

Physics demonstration experiments have the ability to impress. The 'wow' factor element in the selection of possible demonstration experiments for your students should never be dismissed or overlooked (Parker, 2002). Some simple demonstration experiments, which I have found to 'wow' my own students over the years, follow.

Bouncing balls
Position a smaller ball (a rubbery superball of about 5 cm in diameter works best) on top of a basketball and then drop from about shoulder height. The smaller ball sitting on top of the larger ball takes off on rebound and should easily hit the roof. This is

nothing more than the conservation of momentum in action! See Gibbs (1999, p. 44). The mathematical details of this problem are considered in Barger and Olsson (1995).

Leaping Lennie

This is an old favourite of mine. Connect either end of a light yet reasonably long wire to a power pack (one which preferably does not trip until a current of 10 A is exceeded). Lay a section of the wire between a strong horseshoe magnet. Flick the switch on the power pack and watch Lennie the wire leap! It is a simple yet visual demonstration of the motor effect. Here a magnetic force acts on a current-carrying wire which is in the presence of an external magnetic field. The size of the leap will depend on the size of the current that can flow in the wire and the strength of the horseshoe magnet. Reversing the direction of the current flow causes the wire to be pushed hard down into the base of the horseshoe magnet. See Gibbs (1999, p. 191).

Sooty glass tube in water

Holding your finger over one end of a hollow glass tube covered in soot, immerse it in water. The tube should appear a silvery colour and not black. Releasing your finger from the top of the tube allows water to rush in and the silvery effect disappears. The bright silvery colour appearance is due to a thin film of air being trapped within the soot which causes the light to be totally internally reflected at the water–air interface. See Gibbs (1999, p. 123) or Sutton (2003, p. 386, L-39).

Conclusion

Demonstration experiments are an integral part of the teaching and learning process of physics. A good demonstration experiment can give beautiful and striking confirmation of a particular physical principle under discussion. Furthermore, by clarifying difficult concepts, they can be used as an effective teaching tool in helping to aid understanding within the learner. In this paper I have tried to present a collection of demonstration experiments where simplicity is foremost; not only are they simple, but they are also easy to construct, and doable in the sense that they rely on nothing more than readily available materials. Whilst it may be tempting for the teacher of physics to choose any number of more impressive demonstration experiments at their disposal, one must exercise caution. The death of a really good demonstration experiment, in terms of its effectiveness as a pedagogical tool, may result if one imposes too many barriers of mysterious and intimating equipment between the observer and the phenomenon being observed – simplicity is the key!

Acknowledgements

If it were not for the hard ‘behind the scenes’ work of Mr Jan Beks, who gathered together all the equipment and necessary materials, who constructed and put together some of the demonstrations, who tested the remainder, and who kindly offered his support on the day, my session would not have been possible. Thanks are also due to

a former colleague of mine, Mr Warner Neggo, who provided much of the inspiration behind many of the ideas contained in this paper. A special thanks is also made to the Core Physics Department at The Petroleum Institute, who kindly made available one of their laboratories for my session. Finally, I am indebted to Ms Emer Hayes for her comments on an earlier draft of this paper.

References

BARGER, V. AND OLSSON, M. (1995). *Classical mechanics: A modern perspective* (2nd ed.). McGraw-Hill: New York. See problem 4-13 on page 133.

CHIAVERINA, C. (2004). The simplest motor?, *The Physics Teacher*, **42**(9), 553.

EDGE, R. D. (1987). *String and sticky tape experiments*. American Association of Physics Teachers: College Park, MD.

FREIER, G. D. AND ANDERSON, F. J. (1996). *A demonstration handbook for physics* (3rd ed.). American Association of Physics Teachers: College Park, MD.

GABRIELSON, C. (2004). Physics in East Timor, *The Physics Teacher*, **42**(2), 98–101.

GIBBS, K. (1999). *The resourceful physics teacher*. Institute of Physics Publishing: Bristol.

KAGAN, D. (2005). Upright homopolar motor, *The Physics Teacher*, **43**(2), 68.

MILLS, D. R., FETERIS, S. M. AND GREAVES, T. L. (2005). Developing investigative skills through a 'challenge' experiment, in M. Colla (Ed.) *Proceedings of the 16th Biennial Congress of the Australian Institute of Physics* (Vol. 2, pp. 80–83). Australian Institute of Physics: Parkville, VIC.

PARKER, K. (2002). Going for the wow, *Physics Education*, **37**(5), 430–433.

RATHJEN, D., DOHERTY, P., KUTNICK, E. AND THE EXPLORATORIUM TEACHER INSTITUTE (2002). *Square wheels and other easy-to-build, hands-on science activities*. The Exploratorium: San Francisco, CA.

STEWART, S. M. (2005). Force on a current-carrying wire, *The Physics Teacher* (accepted for publication).

STEWART, S. M. AND NEGGO, W. (2005). A simple coat-hanger model for two point source interference, *Physics Education* (accepted for publication).

SUTTON, R. M. (2003). *Demonstration experiments in physics*. American Association of Physics Teachers: College Park, MD.

SYMON, K. R. (1960). *Mechanics* (2nd ed.). Addison-Wesley Publishing Company: Reading, MA.

TAYLOR, M. S. (2002). Spring a surprise, *Physics Education*, **37**(1), 80.

YOUNG, H. D. AND FREEDMAN, R. A. (2000). *Sear and Zemansky's university physics with modern physics* (10th ed.). Addison-Wesley Publishing Company: San Francisco.

Secondary science students' perceptions of learning environment and its association with achievement in biology

Bob Chui-Seng Yong

Department of Science and Mathematics Education, Universiti Brunei Darussalam, Gadong, Brunei

Bruneian students' perform not as well in biology as in other science subjects such as chemistry and physics in the General Certificate of Education Ordinary Level examinations. This has been the case for many years and efforts are being made to find out the underling factors responsible for this. The purpose of the present study was to investigate students' perceptions of classroom learning environment and teacher interpersonal behaviour in biology and determine whether these variables affect their achievements in the subject. The study involved 636 Form 5 science students from 19 government schools in Brunei Darussalam. Students' perceptions of the classroom learning environment were measured using the questionnaire 'What Is Happening In This Class?' and students' perceptions of their teacher's interpersonal behaviour using the questionnaire 'Teacher Interaction'. Results of the study indicated that students' perceptions of their classroom learning environment and teacher interpersonal behaviour were moderately positive. The study also revealed that there were associations between the different dimensions in the two variables, i.e., classroom learning environment and teacher interpersonal behaviour, with achievement in biology. Implications of the findings of this study for better teaching and learning of biology at secondary school level are discussed.

Introduction

Like many countries in the world, the education system in Brunei Darussalam places strong emphasis on science education. This is in response to the rapid advancement in science and technology so that the country will be able to surge forward in keeping pace with the process of modernisation like the rest of the world. Learning science is, therefore, becoming more essential not only for the well-being of the individual but

also for society as a whole. However, there has been a concern over the low enrolment of students in science, particularly at upper secondary level in Brunei Darussalam. Ahmad (1998) reported that only about 20% of students at the upper secondary level participate in science stream classes. He expressed concern at the country's growing inability to fulfill national aspirations of producing sufficient science and technology-based manpower if the trend were allowed to continue unabated.

Beside low enrolment, perhaps an even greater concern has been the low pass rate in science in the General Certificate of Education (GCE) Ordinary level (O-level) examinations. This will certainly thwart national development as the main driving force are citizens who are scientifically literate who will propel the country forwards in this technologically more complex world.

For the past several years, the percentage of students who obtained a credit pass in science was low. For example, the GCE O-level results that were released in 2002 showed that 44.8% of students obtained a credit pass in biology, 52.7% in chemistry and 54.2% in physics. It has been observed that, of the three sciences, the percentage of credit pass for biology was particularly low compared with chemistry and physics. A similar pattern was also observed for GCE Advanced level (A-level) examination results. This observation has generated great interest and prompted the author to investigate reasons for Form 5 science students' low achievement in biology.

In a study on Form 5 science students, Yong (2003a) reported that students encountered enormous problems learning biology in English. Among the problems were an inability of students to understand fully teachers' explanations, lesson notes, practical instructions, and materials in biology textbooks. Analysis of Pearson product-moment correlation showed a higher correlation coefficient was obtained between English language and biology than between English language and chemistry or physics. He suggested that students' achievement in biology was more affected by English proficiency than chemistry or physics.

In another study on the same sample of students, Yong (2003b) found that they did not have very favourable attitudes towards biology. He reported that, though students moderately enjoyed learning biology and considered learning biology important to their every day life, they generally did not have high anxiety, interest, motivation and confidence in learning biology.

Language problems and poor attitudes may not be the only factors that contribute to low achievement in biology. There is now convincing evidence from empirical studies that achievement is influenced by a number of other factors. Among these, classroom and school environment factors were the most important determinants of learning (Walberg, 1986; Walberg, Fraser and Welch, 1986 cited in Henderson, Fisher and Fraser, 2000). Numerous studies have shown that this socio-psychological dimension, particularly those associated with classroom learning environments and teacher interpersonal behaviour, have a strong influence on student learning outcomes (Henderson, Fisher and Fraser, 2000; Poh, 1996; Riah, 1998; Rickards, 1999; Scott, 2003).

Fraser (1986, 1994) reported that classroom learning dimensions were reliable for

predicting students' outcomes. It has been reported that students achieve better when there is greater congruence between actual environment and environment preferred by students (Fraser and Fisher, 1983 cited in Riah, 1998). Studies of senior secondary biology classes in Australia by Henderson, Fisher and Fraser (2000) reported that associations with students' perceptions of their learning environment were stronger for the attitudinal outcomes than for cognitive and practical outcomes. In chemistry theory classes, Riah (1998) reported that students perceived their classroom learning environment moderately positive and dimensions such as teacher support, involvement, and task orientation showed a significant positive association with attitudes. In terms of gender, he reported that boys and girls had different perceptions of their classroom learning environment and that girls seemed to perceive their learning environment more favourably than boys. Poh (1996) assessed O-level secondary students' actual and preferred perceptions of their laboratory learning environments using the Science Laboratory Environment Inventory (SLEI) instrument. He reported that students preferred an environment where there is a high level of student cohesiveness, rule, clarity, and material environment.

Another important socio-psychological dimension that has a strong influence on student learning outcomes is associated with teacher interpersonal behaviour (Henderson, Fisher and Fraser, 2000). For example, in Brunei, Riah (1998) reported that teacher interpersonal behaviour was associated with Form 5 student attitudes and achievement in chemistry. More specifically, he reported that leadership behaviour has a strong positive and significant correlation with students' attitudes while understanding behaviour significantly correlated with achievement. In Australia, Rickards (1999) found that secondary school science students' attitudes scores were higher in classrooms in which they perceived greater leadership, helping/friendly, and understanding behaviours in their teachers. He also reported positive associations between cognitive achievement and co-operative behaviours of teachers. Scott (2003) investigated primary students' perceptions of their teachers' interpersonal behaviour in Brunei Darussalam. She found that leadership, helping/friendly, and understanding behaviours correlated positively with students' achievement in science, while helping/friendly had more impact than other teachers' interpersonal behaviours on students' enjoyment of their science lessons. Studies of senior secondary biology classes in Australia by Henderson, Fisher and Fraser (2000) reported that associations with students' perceptions of their learning environment were stronger for the attitudinal outcomes than for cognitive and practical skills outcomes.

As empirical studies have shown that classroom learning environment and teacher interpersonal behaviour have an important impact on students' outcomes, it was decided to examine these dimensions and their association with achievement in biology. As was mentioned earlier, Form 5 science students encountered enormous problems learning biology in English and they did not have very favourable attitudes towards biology. How did this same sample of students perceive the classroom learning environment and teacher interpersonal behaviour in their biology classes? Were there asso-

ciations between classroom learning environment and teacher interpersonal behaviour with student achievement in biology? How much contribution did these two constructs, i.e. classroom learning environment and teacher interpersonal behaviour, have to the variance in student achievement in biology?

Method

The Questionnaire on What Is Happening In This Class?

Classroom learning environment in biology classes was measured using the Questionnaire on What Is Happening In This Class? (WIHIC) which was adapted from Poh (2000) for lower secondary science classes. Some of the original statements were reworded to make them more suitable and clearer for the students. For example, one statement which read, ‘The teacher goes out of his/her way to help me’ was changed to ‘The biology teacher gives his best to help me’. In each statement, the word ‘biology’ was added, thus describing and emphasising specifically their biology teacher or biology lessons/classes each time they responded to the statements in the questionnaire.

The present version used a five-point format ranging from *never*, *seldom*, *sometimes*, *often*, and *always*, and scores from 1 to 5. The forty-nine items were arranged in a cyclic order.

The personal form of WIHIC adapted from Poh (2000) has forty-nine statements which were categorised into seven dimensions or scales of the biology classroom environment, viz., student cohesiveness, teacher support, involvement, investigation, task orientation, co-operation, and equity. The description and sample item of each scale is presented in Table 1.

The Questionnaire on Teacher Interaction

Teacher interpersonal behaviour was measured using the Questionnaire on Teacher Interaction (QTI) which was adapted from Goh and Fraser (1997) for elementary schools in Singapore. In the present study the same questionnaire was used as it was considered suitable for Bruneian students. This simple version has the advantage of enabling the student to understand the items more fully and thus make a better judgement of their teacher’s interpersonal relationship with them. In each item the word ‘biology’ was inserted so the new statement then read ‘This biology teacher cares about us’, thus describing and emphasising specifically their biology teacher each time they responded to the items in the questionnaire.

The QTI has forty-eight items which were categorised into eight teacher behaviour scales, viz., Leadership (DC), Helping/friendly (CD), Understanding (CS), Student responsibility/freedom (SC), Uncertain (SO), Dissatisfied (OS), Admonishing (OD), and Strict (DO) behaviours. A description and sample item of each scale is represented in Table 2. Each of the eight behaviour scales occupied a sector of the octagon which has two axes intersecting at right angles at the centre (see Figure 1). The vertical axis represents an Influence dimension (Dominance D and Submission S) while the horizontal axis represents a Proximity dimension (Co-operation C and Opposition O). The two

Scale	Description	Item
Student cohesiveness	Extent to which students know, help and are supportive of one another.	I make friends with students in biology class.
Teacher support	Extent to which the teacher helps, befriends, trusts and is interested in students.	My biology teacher takes a personal interest in my studies.
Involvement	Extent to which students participate actively and attentively in class discussions and activities.	I discuss my ideas with both my teacher and friends in biology.
Investigation	Extent to which students use skills and processes of inquiry in problem-solving and investigation.	I carry out investigations to test my ideas in biology class.
Task orientation	Extent to which students complete their activities and stay on course in the subject matter.	Getting some work done in biology is important to me.
Co-operation	Extent to which students co-operate with one another and share resources.	I co-operate with other students when doing biology assignments.
Equity	Extent to which students are treated equally by the teacher.	The biology teacher gives as much attention to my question as to other students in the class.

Table 1: Scale, description and sample test items in the WIHIC.

axes represents opposite behaviours, with the DS axis for dominance and submission and the CO axis for co-operation and opposition, as shown in Figure 1.

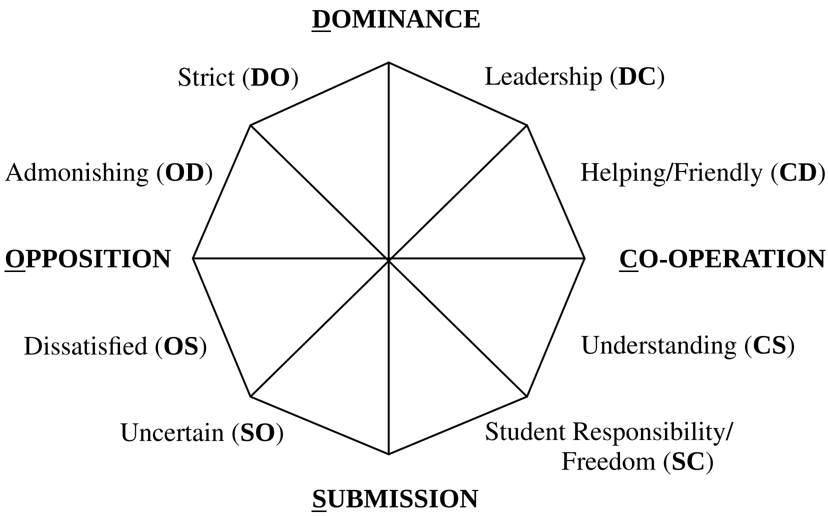


Figure 1: The model of interpersonal behaviour.

The present version of QTI has a five-point Likert response format ranging from *never*, *seldom*, *sometimes*, *often*, and *always*, with the aim of giving students a wider choice and more accurate judgement of their teacher's relationship with them.

Administration of WIHIC and QTI

WIHIC and QTI were part of a questionnaire which was developed to investigate Form 5 student achievement in biology. The questionnaire consisted of six dimensions which encompassed aspects such as students' attitudes towards learning biology, biology teacher's teaching strategies, students' motivation, teacher interpersonal behaviour (QTI), biology classroom learning inventory (WIHIC) and learning biology in English. The questionnaire was distributed to Form 5 science students with the help of their biology teachers in August 2001. Students were allowed to take the questionnaire home to complete and returned it the following day.

Sample

The sample of this study consisted of 636 Form 5 science students from 19 government secondary schools in the four districts of Brunei Darussalam. This represents 47% of the science students who took biology. Of the sample, 393 were girls and 243 were boys and their average age was 16.2 years.

Biology Achievement

This was determined by the grades that they obtained in the GCE O-level examinations

Scale	Description	Item
Leadership (DC)	Extent to which teacher provides leadership to the class and holds student attention.	We all listen to the teacher.
Helping/ Friendly (CD)	Extent to which the teacher is friendly and helpful towards students.	The teacher is friendly.
Understanding (CS)	Extent to which the teacher shows understanding/concern/care for students.	The teacher trusts us.
Student Responsibility/Freedom (SC)	Extent to which students are given opportunities to assume responsibility for their own activities.	The teacher gives us a lot of free time in class.
Uncertain (SO)	Extent to which the teacher exhibits his/her uncertainty.	The teacher isn't sure.
Dissatisfied (OS)	Extent to which the teacher shows unhappiness/dissatisfaction with students.	The teacher is unhappy.
Admonishing (OD)	Extent to which the teacher shows anger/temper/impatience in class.	The teacher gets angry quickly.
Strict (DO)	Extent to which the teacher is strict with and demanding of students.	The teacher is strict.

Table 2: Scale, description and sample test items in the QTI.

which they sat in November 2001. The results were released in February the following year.

Results and discussion

Reliability of WIHIC and QTI

Statistical analysis revealed that both the instruments were reliable and valid for the study. Internal consistency indices (alpha reliability) for the various scales in WIHIC ranged from 0.77 to 0.82 when the individual student was used as the unit of analysis (see Table 3).

Scale	Alpha reliability
Student Cohesiveness	0.77
Teacher Support	0.82
Involvement	0.81
Investigation	0.82
Task Orientation	0.81
Co-operation	0.77
Equity	0.79

Table 3: Internal consistency reliability (Cronbach alpha coefficient) for WIHIC.

In the case of QTI, the simple version adapted from Goh and Fraser (1997) gave values which ranged from 0.61 to 0.82 (see Table 4) and this was found to be slightly higher than those reported in their studies.

Scale	Alpha reliability
Leadership (DC)	0.80
Helping/Friendly (CD)	0.82
Understanding (CS)	0.79
Student Responsibility/Freedom (SC)	0.62
Uncertain (SO)	0.63
Dissatisfied (OS)	0.72
Admonishing (OD)	0.75
Strict (DO)	0.61

Table 4: Internal consistency reliability (Cronbach alpha coefficient) for QTI.

Students' perceptions of classroom learning environment in biology classes

Scale mean scores indicated that Form 5 science students perceived their biology classes as having high levels of student cohesiveness, teacher support, task orientation, co-operation and equity, and low levels of involvement and investigation in biology classes

(see Table 5). The present findings were congruent with those reported by Riah (1998) in chemistry theory classes.

Scale	Mean	SD
Student Cohesiveness	28.39	4.02
Teacher Support	27.42	4.70
Involvement	19.32	4.99
Investigation	20.13	4.83
Task Orientation	25.79	4.66
Co-operation	25.70	4.48
Equity	26.39	4.93

Table 5: Scale means and standard deviations (SD) of WIHIC.

Students' perceptions of teacher interpersonal behaviour in biology classes
Scale means in Table 6 showed that students perceived their biology teachers as helping and friendly, good leaders, understanding and strict, ones who did not give much student responsibility and freedom, and were less uncertain, dissatisfied or admonishing. Figure 2 showed the sector profile of students' perceptions of interpersonal behaviour of biology teachers. Based on the Dominance–Submission and Co-operation–Opposition dimensions, the pattern obtained in Figure 2 suggested that biology teachers in Brunei Darussalam exhibited co-operative and dominant tendency.

Scale	Mean	SD
Leadership (DC)	24.12	4.09
Helping/Friendly (CD)	24.43	4.09
Understanding (CS)	22.98	4.13
Student Responsibility/Freedom (SC)	15.66	3.57
Uncertain (SO)	10.24	3.27
Dissatisfied (OS)	11.17	3.77
Admonishing (OD)	11.29	4.12
Strict (DO)	19.48	3.82

Table 6: Scale means and standard deviations (SD) of QTI.

In this study, both simple and multiple correlation analyses were employed to investigate associations between students' perceptions of classroom learning environment and teacher interpersonal behaviour with students' achievement.

Associations between students' perceptions of classroom learning environments and students' achievement in biology
Simple correlations showed that all the WIHIC scales were statistically significant with

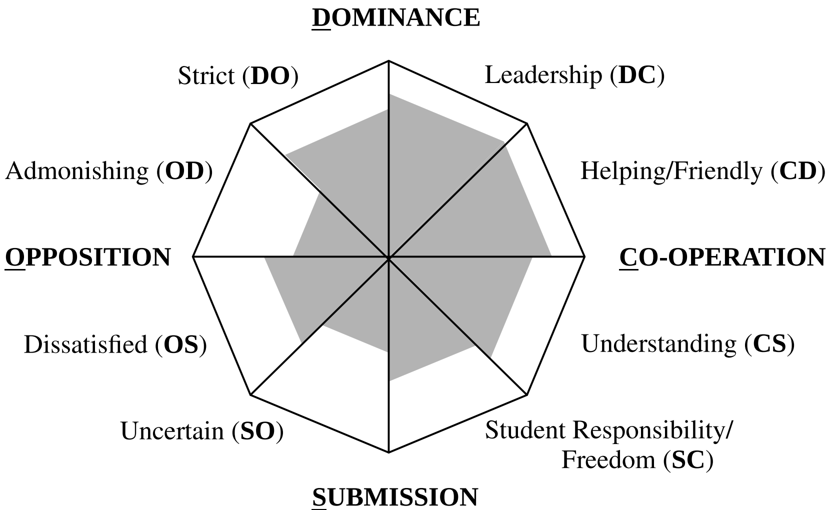


Figure 2: Sector profile of students' perceptions of interpersonal behaviour of biology teachers.

Scale	r	β
Student Cohesiveness	0.19^{***}	0.19^{**}
Teacher Support	0.17^{***}	
Involvement	0.19^{***}	0.13^{**}
Investigation	0.11^{**}	
Task Orientation	0.29^{***}	0.27^{***}
Co-operation	0.04	-0.26^{***}
Equity	0.24^{***}	0.13^{*}
Multiple R	0.37^{***}	
R^2	0.14	

$N = 636$ students $^{***}p < 0.001$ $^{**}p < 0.01$ $^{*}p < 0.05$

Table 7: Associations between WIHIC scales and achievement of biology lessons in terms of simple correlations (r) and standardised regression coefficients (β).

achievement in biology except co-operation (see Table 7). The standardised regression coefficients (β) obtained indicated that student cohesiveness, involvement, task orientation and equity showed significant positive correlation whilst co-operation showed significant negative correlation with students' achievement in biology. The multiple regression (R) was 0.37, and the R^2 value of 0.14 indicated that 14% of the variance in students' achievement was attributed to their perceptions of their classroom learning environment. Thus, teachers wishing to enhance students' achievement in biology should provide more student cohesiveness, involvement, task orientation, and equity, whilst encouraging less co-operation among the students in biology classes.

Scale	r	β
Leadership (DC)	0.27^{***}	
Helping/Friendly (CD)	0.21^{***}	
Understanding (CS)	0.20^{***}	
Student Responsibility/Freedom (SC)	0.16^{***}	0.21^{***}
Uncertain (SO)	-0.23^{***}	-0.17^{**}
Dissatisfied (OS)	-0.17^{***}	-0.15^{*}
Admonishing (OD)	-0.09^{*}	
Strict (DO)	0.21^{***}	0.21^{***}
Multiple R	0.38^{***}	
R^2	0.15	

$N = 636$ students $^{***}p < 0.001$ $^{**}p < 0.01$ $^{*}p < 0.05$

Table 8: Associations between QTI scales and achievement of biology in terms of simple correlations (r) and standardised regression coefficients (β).

Associations between QTI scales and achievement of biology

In achievement, simple correlations showed that all the eight scales in QTI were statistically significant (see Table 8). Five scales were associated positively with achievement such as leadership, helping and friendly, understanding, student responsibility and freedom, and strict, while three scales were associated negatively such as uncertain, dissatisfied, and admonishing.

The multiple correlation (R) obtained was 0.38, and the R^2 value was 0.15 which indicated that 15% of the variance in students' achievement in biology, which was highly significant, was attributed to teacher interpersonal behaviour. The standardised regression coefficients (β) obtained indicated that student responsibility and freedom, and strict, have the same positive impact on students' achievement in biology. On the other hand, uncertain and dissatisfied behaviours have an opposite effect on students' achievement. Thus, teachers wishing to enhance student achievement in biology should allow more student responsibility and freedom, and at the same time they should be stricter while being less uncertain and dissatisfied.

Conclusion

The results of the present study showed that students had moderately positive perceptions of their classroom learning environment and teacher interpersonal behaviour in biology classes. In view of this, some aspects of their learning environment needs to be improved if students are to achieve a higher success rate in biology. In terms of classroom learning environment, they perceived it as having high levels of student cohesiveness, teacher support, task orientation, co-operation and equity, and low levels of involvement and investigation.

The study showed that nearly all the seven scales in WIHIC showed significant associations with achievement with the exception of co-operation. Associations between students' perceptions of their classroom learning environment in biology and achievement outcomes reported in the present study suggested that more student cohesiveness, involvement, task orientation, and equity, and less co-operation among the students are likely to promote better achievement in biology.

In terms of interpersonal behaviour, biology teachers in Brunei Darussalam were perceived as dominant and co-operative. They were in control of the class (leadership), strict, helping/friendly, and understanding. They gave little student responsibility/freedom and demonstrated low uncertain, dissatisfied and admonishing behaviours.

The study showed that significant associations were obtained between all the QTI scales and achievement. More specifically, achievement in biology was positively associated when teachers demonstrated leadership, helping/friendly, understanding, student responsibility/freedom, and strict behaviours. The converse was true when teachers were perceived as uncertain, dissatisfied and admonishing. The multiple regression (R) indicated that there were associations between students' perceptions of teacher interpersonal behaviour and achievement. Cognitive achievement was higher when teachers provided some degree of student responsibility/freedom and were strict, and lower achievement when teachers demonstrated uncertain and dissatisfied behaviours.

The findings of the present study have important implications for biology teachers who wish to promote better achievement in upper secondary science students. The study provided useful information and insight into students' perceptions of their classroom learning environment and their teacher interpersonal behaviour in biology classes. As previous studies had indicated that a key to improving student achievement is to create learning environments which emphasise those characteristics which have been found to be linked empirically with achievement (Rickards, 1999), it is imperative that teachers should take appropriate interventions, based on the present findings, to provide a more conducive classroom learning environment in order to achieve better results in biology.

References

GOH, S. C. AND FRASER, B. J. (1997). Adaptation of the questionnaire on teacher interaction for elementary grades, *Asia Pacific Journal of Education*, **17**(2), 102–116.

FRASER, B. J. (1986). *Classroom environment*. Croom Helm: London.

FRASER, B. J. (1994). Research on classroom and school climate, in D. L. Gabel (Ed.), *Handbook of research on science teaching* (pp. 493–541). Macmillan: New York.

HAJI AHMAD BIN HAJI JUMAT (1998). Science, mathematics and technical education for human resource development: A Brunei Darussalam perspective, in Y. P. Leong, L. M. Ferrer, and M. Quigley, (Eds), *Science, mathematics and technical education for national development* (pp. 4–24). Universiti Brunei Darussalam: Gadong.

HENDERSON, D., FISHER, D. AND FRASER, B. (2000). Interpersonal behaviour, laboratory learning environments, and students outcomes in senior biology classes, *Journal of Research in Science Teaching*, **37**(1), 26–43.

POH, S. H. (1996). A study of biology laboratory learning environment in Brunei Darussalam, in M. Quigley, P. Veloo and K. Y. Wong (Eds), *Assessment and evaluation in science and mathematics education: Innovative approaches* (pp. 272–280). Universiti Brunei Darussalam: Gadong.

POH, S. H. (2000). Lower secondary science questionnaire – Brunei (1). Science and Mathematics Education Centre (SMEC). Curtin University of Technology: Perth.

RIAH, H. (1998). *Learning environment and its association with student outcomes in chemistry in Brunei Darussalam's secondary schools.* Unpublished DScEd thesis. Curtin University of Technology: Perth.

RICKARDS, T. (1999). Cultural factors and sex differences in science teacher–student interpersonal behaviour and associations with student attitude and achievement, in M. A. (Ken) Clements and Y. P. Leong. (Eds), *Cultural and language aspects of science, mathematics and technical education* (pp. 133-142). Universiti Brunei Darussalam: Gadong.

SCOTT, R. (2003). Students' perceptions of science teachers' classroom interaction, in S. P. Loo, A. Aminah, S. Yoong, T. S. A. Azian, L. W. Lee and S. C. Toh (Eds), *ICASE 2003 World Conference on Science and Technology Education* (pp. 155-165). ICASE: Penang, Malaysia.

WUBBELS, T. (1993). Teacher-student relationships in science and mathematics classes, in B. J. Fraser (Ed.), *Research implications for science and mathematics teachers* (Key Centre Monograph No. 5) (Vol. 1, pp. 65–73). Curtin University of Technology: Perth.

YONG, B. C. S. (2003a). Language problems in the learning of biology through the medium of English, *Journal of Applied Research in Education*, **7**(1), 97–104.

YONG, B. C. S. (2003b). Secondary students' attitudes towards biology and their achievement in GCE O-level examinations, in H. S. Dhindsa, S. B. Lim, P. Achleitner and M. A. (Ken) Clements (Eds) *Studies in science, mathematics and technical education* (pp. 39–44). Universiti Brunei Darussalam: Gagond.

An effective approach to online physics by incorporating home-based experiments

Wilfred Riego

Department of Academics/Engineering, College of the North Atlantic–Qatar, Doha, State of Qatar

In the area of education, online environments for learning now exist and are increasing at an alarming rate. Such environments offer great potential and huge possibilities for education, especially in the Middle East where online learning is still relatively new. Colleges and universities in the Western world are all getting involved in using this method to deliver courses of various disciplines. However, their potential may only be realised if teachers can accommodate their personal theories, beliefs, and practices to suit the characteristics of the new environment. It is not just a matter of gathering notes together and presenting them online but, instead, new ways have to be defined, evolved and adapted to the new environment. We need to ensure that traditional learning and e-learning are not only compatible, but also complementary. The task of offering science subjects online is very difficult to deliver, especially when experiments are a crucial part of the evaluation process. Interactive virtual activities and simulations have been developed and used, with some educators endorsing such methods as a replacement for traditional laboratory classes. The question however remains: are virtual experiments the same as traditional experiments? I devised a method where students can actually perform experiments similar to those they would normally carry out in a traditional laboratory class. The experiments may be different but the concepts, procedures, and the end results are the same. The 'new' experiments are experiments which can be done at home using readily available materials.

Introduction

In the area of education, there exist online environments for learning. Online learning is very popular, especially amongst those who cannot afford to attend regular classes because of professional or personal needs. Such an environment offers great potential and

huge possibilities for education, especially in the Middle East where online learning is still relatively new. There is a ‘gold rush’ of colleges and universities in the Western world wanting to get involved in using online methods to deliver courses of various disciplines. However, their potential may only be realised if teachers can accommodate their personal theories, beliefs, and practices to suit the characteristics of the new environment. It is not just a matter of gathering notes together and presenting them online, but instead new ways have to be defined, evolved and adapted to the new environment. We need to ensure that traditional learning and e-learning are not only compatible, but also complementary.

Towards online delivery

The task of offering science subjects online is very difficult, especially when one considers that experiments are a crucial part of the evaluation process. Interactive virtual activities and simulations have been developed and used, with some educators endorsing such methods as a replacement for traditional laboratory classes. The question however remains: are virtual experiments the same as traditional experiments? I believe that to deliver an online physics course the experiments must be a combination of traditional and virtual learning. A mix of indirect traditional and online methodology is the solution to a better way of understanding and learning key concepts in physics over the Internet.

I devised a method where students can actually perform experiments similar to those performed by traditional methods. The experiments may be different but the concepts, procedures, and the end results are the same. The ‘new’ experiments are experiments which can be done at home using commonly available materials that can either be readily purchased or found around the home. As an example, the simple physics kit shown in Figure 1 has been sent to students to complete. It consists of a spring balance, spring, a digital thermometer, solid sample, string, Styrofoam cup and a small piece of aluminium.

The development of the physics kit grew out of my practical experiences gained from twenty-odd years of teaching physics and science. At the end of the semester, the kit is returned by the student for a partial refund. The rest of the course is done online through the College of the North Atlantic Distributive Learning Service using WEBCT. In the online delivery mode, learning materials such as experiment information, data sheets, video demonstrations on how the experiment is to be performed, and so on are all available.

As in the traditional mode, students are expected to prepare laboratory notes to document observations, and to submit formal laboratory reports to their teachers to demonstrate their understanding of related concepts. The experimental notes provided to students include detailed instructions on preparing a formal written laboratory report for submission.

Figure 1: Physics apparatus kit.

Conclusion

I am already teaching physics online to students in Canada while teaching traditionally in Doha, Qatar. Online education is definitely here to stay and by using this combination of online and hands-on home-based experiments, doing physics online becomes more effective as it gives the student a better understanding of the key physical concepts involved.

Combustion: A collection of lecture demonstrations

Paul Rostron

Department of Chemistry, The Petroleum Institute, Abu Dhabi, United Arab Emirates

Introduction

We start our discussion with fire – an apparently simple yet complicated process that even now is not fully understood. Within a flame, there are many thousands of chemical reactions involving short-lived and highly-reactive species called free-radicals. These are substances that do not fill their normal complement of bonds. Our journey through combustion will ignore much of this highly-detailed knowledge, and focus on the theoretical basis of combustion, *the fire triangle*. We will look at the elements required to produce combustion, how to extinguish it, and how to improve the efficiency of combustion.

The fire triangle

There are three essential elements required for combustion: oxygen, fuel and heat. This forms a triangle of interconnected elements (see Figure 1). Combustion may only occur if all three are present.

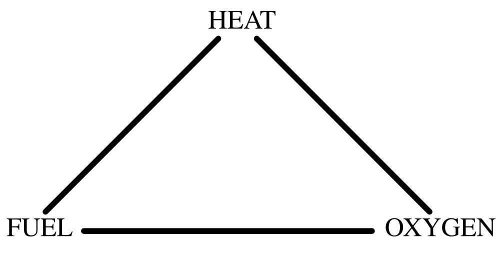


Figure 1: The fire triangle.

Oxygen
Oxygen is a gas which is present in air at 20.9% by volume. Fortunately for us, the oxygen concentration is below 30%. Above this concentration, we become flammable. Oxygen is reactive because it has a high affinity (attraction/desire) for electrons and will remove electrons from every other element except fluorine. The removal of electrons from a substance is called oxidation and combustion is unrestrained oxidation. The main difference between combustion and other forms of oxidation, such as redox reactions, electrochemical cells, and respiration, is that the energy liberated during the reaction (all these reactions are spontaneous and therefore have a nett release of energy) has nowhere to go and therefore is used to increase the kinetic energy of the particles involved. Since the kinetic energy of a particle is responsible for temperature, it means that combustion results in elevated temperatures.

Fuel
There are many definitions of a fuel, but all fuels share one thing in common: they are good sources of easily liberated electrons. An ideal fuel may have many of the following properties:

- easily liberated electrons;
- large release of energy upon reaction;
- high energy density;
- mixes well with air;
- does not have harmful combustion products.

Heat
It is fortunate that no combustion can occur without a source of heat, as it would mean that all flammable substances would combust upon exposure to air. This does not happen because in order for a reaction with oxygen to occur, chemical bonds must first be broken. Once this happens, the energy supplied during the combustion process can then be used to break other nearby bonds, initiating a chain reaction.

The initial input of energy may be supplied as a flame, a spark, as frictional heating, or even light. The amount of energy required varies enormously and depends upon the intimacy of mixing of fuel and oxygen and the chemical specifics. For example, a candle needs a great deal of heat, since the wax needs to be vaporised before combustion can occur, whereas hydrogen and chlorine need only a flash of light.

The demonstrations

Each of the following demonstrations are chosen to demonstrate the fire triangle, starting with the Bunsen burner.

The Bunsen burner

With the air hole closed, a bright yellow, relatively cool flame results. The yellow colour is due to incandescent particles of carbon. These can easily be seen by placing a cool object in the flame, which quickly gets coated with soot. The carbon is the result of incomplete combustion of the hydrocarbon fuel. During combustion the hydrogen is easily removed and reacts with oxygen in air to form water:

$$CH_4 + O_2 \longrightarrow C + 2H_2O.$$

This is called incomplete combustion and results from the lack of oxygen in the mixture. Oxygen diffuses through the flame from the air and also explains why the flame is large and bilious. Some blueness can be seen and this is due to a side reaction producing carbon monoxide. Carbon monoxide is a highly toxic compound and its production means that incomplete combustion can be extremely dangerous to us.

If air is premixed with the fuel, it means that the combustion is not restricted to diffusion mixing with oxygen and so more complete combustion occurs:

$$CH_4 + 2O_2 \longrightarrow CO_2 + 2H_2O.$$

The flame is much hotter as more combustion occurs. The flame is less bilious and a cone forms. Inside the cone, unburnt air and fuel co-exist, with the flame front appearing dark blue. One must however be careful to balance the ratio of fuel and air. If the mixture is too lean (too much air), the flame will extinguish, whereas if it is too rich, incomplete combustion will occur. However, if the mixture is perfect, a further problem will ensue. The flame front will move through the mixture at the speed of sound and the resulting massive exotherm will result in an explosion.

Methane detonation

Methane and air is explosive between the limits of 11% and 20%. Above this, the mixture is flammable and below it will not burn.

In this demonstration, we fill a metal can such as a paint can (with a prised off lid) with methane and rest it on a tripod. The gas escaping from the hole in the top is lit and as the gas leaves, air enters from the hole underneath. Initially the gas leaving the can is a rich mixture and a yellow flame ensues. As air mixes in, the percentage of methane decreases slowly until 20% is reached. When this happens all of the methane in the can ignites, resulting in an explosion, blowing off the lid. Please note the safety requirements in this demonstration. Also note that this must occur with methane and not propane (methane is lighter than air).

Demonstrations on the fire triangle

As discussed earlier, the fire triangle requires fuel, oxygen and heat to produce combustion. We can demonstrate this by looking at the different ways of extinguishing a fire.

Removal of heat
Cooling of the fire can put out a fire. For this we use water. Water has an extremely high energy of vaporisation and so will cool a fire sufficiently to put it out.

Removal of fuel
There are several methods available here, the most common being a dry inert powder which isolates the fuel from the fire. For liquid fires, a foam can be used.

Removal of air
Since air is the source of the oxygen, removing the air will extinguish the fire. This can be achieved by smothering the fire with a dense non-flammable gas, such as carbon monoxide

Effect of particle size

As we have already seem, gaseous fuels need good mixing with oxygen if they are to combust well. The same applies to solid and liquid fuels. Liquids are relatively easy to atomise, but solids often require agitation. These are generally categorised as dust explosions and can be extremely violent. Grain silos present a serious risk of explosion and measures must be put in place to eliminate sparks or flames.

Custard powder
Custard is a fuel, we eat it to provide energy. In exactly the same way, custard powder will combust when mixed with oxygen. The problem is that it is often very difficult to mix a solid with air sufficiently well for good combustion, hence the apparatus shown in Figure 2.

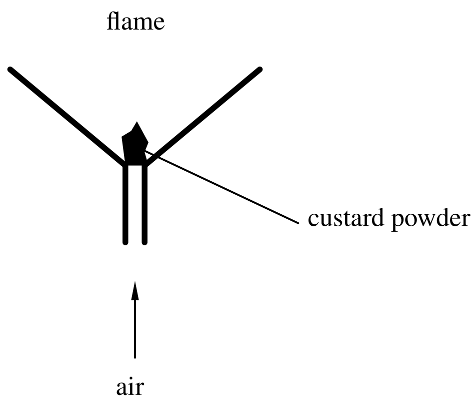


Figure 2: Set-up used to demonstrate the combustion of custard powder in air.

Pyrophoric lead
Metals are excellent sources of electrons for oxygen. This is a neat way of demonstrating this. One normally considers lead to be relatively inert – after all, it was for many years an excellent roofing material! However, if the particle size is small enough, it will react quite vigorously with air. In this experiment nanoparticles of lead have been made. When sprinkled into the air they combust.

Metals

Most metals have to be made. Only gold, silver, copper, platinum, and mercury can exist as metals naturally. This means that metals react with oxygen to donate electrons to oxygen.

Aluminium
Whilst one could make nanoparticles of aluminium, a more interesting demonstration is to investigate why aluminium is unreactive to air in the first place. Aluminium is an extremely reactive metal and it should be impossible to make anything with this metal, yet it is a widely used construction metal. The reason for this is that it forms a flat oxide layer. This prevents further oxidation from occurring protecting the metal. It is possible to disrupt the oxide layer by the addition of mercuric chloride to the metal. This prevents the oxide from forming a flat layer, and so the underlying metal can react. As the conference demonstration showed, the metal can get very hot.

Metals that can react with metal oxides
Another way that metals can get rid of their electrons is to take oxygen from a less reactive metal oxide. This is a reaction between a solid metal and a solid but less reactive metal oxide. The more reactive metal removes oxygen from the less reactive metal, reducing it to metal. The more reactive metal reacts with the oxygen to produce a large excess of energy. One advantage of this is that the oxygen is chemically bound next to the metal and so the reaction can be extremely energetic.

Zinc Powder: As a calibration experiment, observe how powdered zinc reacts with air. The metal burns producing white smoke, and burns further upon stirring.

Zinc powder and copper oxide: In this reaction equal quantities of zinc and a less reactive metal oxide, in this case copper oxide, are mixed and heated. The reaction is much more vigorous than zinc alone, and copper metal is produced.

Copper metal and magnesium metal: Magnesium is more reactive than zinc and so a more exothermic reaction is to be expected.

Chemical sources of oxygen

The idea that the oxygen does not have to be a gas means that we can have many more possibilities to improve the combustion process. In fact there are so many possibilities,

some of which do not even contain oxygen, that we must redefine the concept of the oxygen acceptor to that of an oxidiser.

Metals and peroxides, perchlorates

Metal peroxides contain easily liberated oxygen. Again, since they are solids they can be intimately mixed with the fuel, resulting in excellent combustion.

Ammonium dichromate

Another possibility is to have both oxidiser and fuel as elements within the same compound. This intimate mix results in extremely good combustion, almost resulting in an explosion.

Nitrogen tri-iodide

This compound is extremely sensitive. The amount of energy required to initiate a reaction is extremely small. Consequently, once initiated, the whole sample combusts and the material typically burns with a supersonic flame front. This results in a pressure wave that builds up rapidly and causes the material to explode.

Conclusions

Combustion is an incredibly entertaining branch of chemistry. We can use it to explain many fundamental concepts within chemistry. Students usually find exothermic reactions extremely entertaining, and one can use this to get students to understand many of the more difficult topics. I have also shown that it is possible to demonstrate safely some potentially dangerous experiments. However, as a demonstrator it is vitally important that you perform a thorough risk assessment before attempting many of these experiments. I also strongly recommend that you practise each experiment several times before demonstrating them in front of students. In summary, one must ensure that the following are obeyed:

- a thorough risk assessment is completed;
- fire extinguishers are close to hand;
- students are a suitable distance away, preferably standing;
- emergency procedures are planned ahead;
- students must wear eye protection;
- consider the ventilation; is it suitable?
- you and the technician are clear about what you are doing;
- do not be tempted to increase quantities.

Enhancing teachers' proficiency for better teaching and learning of physics at secondary level

Andrew A. Baimba,[1] Kofi Agyeman[2] and Desmond P. Brown[1]

[1]*Department of Science and Mathematics Education, Universiti Brunei Darussalam, Gadong, Brunei*
[2]*Department of Physics, The Petroleum Institute, Abu Dhabi, United Arab Emirates*

The early 1980s witnessed the emergence of a new frontier in science education research that brought to the fore the discrepancy that exists between what science teachers teach and what students learn. Since then, many studies have been undertaken concerning physics education at secondary school and university levels. There is a consensus among physics educationists that students bring with them to the classroom initial processes of knowledge and thinking that are often at variance with scientific ones. These structures often include intuitive concepts or 'alternative conceptions' that have proven to be very resistant to change. Publication of many research reports on students' alternative conceptions, and the introduction of new teaching models that perceive 'learning as active construction of new knowledge' by the learner have neither improved nor produced remarkable outcomes. Students' alternative conceptions on fundamental physics topics continue to persist. This paper reports findings of studies that investigated the prevalence of alternative physical conceptions held by Papua New Guinean and Bruneian secondary school teachers and teacher trainees and strategies that were employed to modify them. The paper suggests how university physics educators can enhance the teaching and learning of physics at the secondary school level.

Introduction

A number of studies since the early 1980s have shown the discrepancy between what physics teachers think they teach and what students learn (McDermott, 1984; Hestenes, Wells and Swackhamer, 1992). There is a consensus among physics educationists that students bring to the classroom initial processes of knowledge and thinking that are

often at variance with scientific ones. These structures often include intuitive concepts or 'alternative conceptions' that have proven to be very resistant to change. One instrument that has contributed greatly to making known the prevalence of alternative conceptions amongst students is the Force Concept Inventory (FCI) developed by Hestenes, Wells and Swackhamer (1992). This instrument has been administered to more than 20 000 students and 300 physics classes spanning the range from secondary school to post-graduate level (Hestenes, 1998). Results from these studies provide compelling evidence that there are serious problems with physics instruction. The results further suggest that most physics teachers are oblivious to the huge gap between what they think they are teaching and what students are actually learning (Lightman and Sadler, 1993). More specifically, Hestenes et al. (1992) reported that for typical university physics courses, while nearly 80% of the students could state Newton's third law at the beginning of the course, FCI data showed that less than 15% of them fully understood it at course conclusion. Heuvelen (1991) in his study on a typical introductory level physics class found that 20% of the students entering the first semester of the course were Newtonian (as opposed to Aristotelian) thinkers. At the end of the first semester, after his best teaching efforts, the fraction rose by a mere 5% from 20% to 25%. These results, plus others from physics education research (PER) lead to the conclusion that students' marks are not a true reflection of their conceptual understanding of what they are taught in physics. Students are able to solve problems on physics tests with inadequate understanding of the concepts involved (Hestenes, 1992; Chinn and Brouwer, 1993). Stinner (1994) reported that even students who earn high marks in a typical introductory physics course often cannot (i) apply basic physical principles to realistic situations, (ii) solve realistic problems, (iii) perceive or resolve contradictions involving their preconceptions, or (iv) organise the ideas of physics hierarchically. Stinner (1994) believes that what such students actually do is to learn to solve standard problems rapidly using random-search methods that do not require much physical reasoning.

Publication of many research reports on students' alternative conceptions (Hestenes et al., 1992; McDermott, 1991), and the introduction of new teaching models that perceive learning as the active construction of new knowledge by the learner (Hewson and Hewson, 1983; Hake, 1998) have neither improved nor produced remarkable outcomes. Students' alternative conceptions on fundamental physics topics continue to persist (Baimba and Brown, 2003). In seeking an explanation, some researchers note that the structure of a typical introductory physics course has remained essentially static for almost forty years. In this structure the emphasis is on covering material or providing background vocabulary for further study rather than developing students' conceptual understanding, problem-solving, thinking, and modelling skills (Stinner, 2003). Other studies have shown that the high pace of standard courses drives students to adopt non-thinking behaviour even when they would prefer to develop a deeper conceptual understanding (Niedderer, Berthge, Meyling and Scheker, 1992). Unfortunately, this is the type of structure that many physics teachers and trainees experience.

It is little wonder therefore that studies on teachers' understanding of scientific concepts generate concern about the inadequacy of the pedagogical content knowledge of science teachers and their inability in helping students to understand complicated scientific concepts (Ameh and Gunstone, 1985; Enoch and Gabe, 1984; Kruger, 1990). The studies undertaken and reported in this paper came about as a result of these findings. The objectives were (i) to investigate the prevalence of alternative physical conceptions held by Papua New Guinean and Bruneian secondary school teachers and teacher trainees, and (ii) to identify strategies that could be employed to modify these conceptions. We believe that in order to appreciate students' conceptual difficulties in physics the teacher must first realise that they themselves may be subject to similar alternative conceptions and that unless they rectify those misconceptions in themselves then they are unlikely to be of much help to their students. Hestenes (1998) reported that teachers with low FCI scores are unable to raise student scores above their own.

Methodology

To identify and modify the teachers and teacher trainees' alternative conceptions, the researchers employed strategies similar to those recommended by McDermott, Shaffer and Constantinou (2000) who showed that in order to convince a student to change a mental model it is necessary to guide the student to a situation where there is conflict with what is observed and what the student's mental model predicts. The student is then helped to resolve the conflict by amending the model.

Sample

The sample comprised provincial secondary school science teachers in Papua New Guinea (PNG) and science teacher trainees at Universiti Brunei Darussalam (UBD). The number of PNG science teachers varied from seven at the inception of the project and increased steadily to fifteen at the close of the project. They were all trained and qualified with teaching experience ranging from three to ten years. The seven initial teachers were those who had volunteered to participate in a study on how to improve physics education at the secondary school level that was undertaken by the Department of Physics, University of Papua New Guinea (UPNG).

The UBD sample was drawn from students pursuing three separate pre-service teacher education programmes. The first group comprised students pursuing a three-year Certificate in Lower Secondary Science Education (CLSSE). Entry requirement into this programme is five General Certificate of Education (GCE) Ordinary levels ('O' levels). The students are taught both science and professional courses in the Faculty of Education. The second and third groups comprised students pursuing Bachelor of Education for General Science (BEd (General Science)), and Bachelor of Science in Education (BScEd) respectively. Both are four-year (eight semester) programmes. Entry requirements are one GCE Advanced level ('A' level) for the BEd, and two GCE 'A' levels for the BScEd. The BScEd students were either physics majors and mathematic minors, or verse versa. Their total number was seventy-five (twenty-five final year and

fifty third year). They had completed either three or five semesters studying courses in physics and were enrolled in two semester-long courses in methods of teaching secondary school physics. Most of the investigations were carried out on the BScEd group even though some of the test items were also administered to the CLSSE and BEd teacher trainees.

Instruments and data collection

Test items were designed on various concepts but those discussed in this paper investigated displacement, acceleration, free fall and the relationship between force and motion. Some of the concepts have been widely investigated and reported on in the literature (Osborne and Freeman, 1989) but were used as 'mind capture activities' while teaching the unit on 'alternative conceptions' which is a component of the physics methodology syllabus for the BScEd group.

The test items

The test items were administered without prior warning on separate days to the trainees during normal lecture and tutorial sessions. Test Item 2.1 on parabolic motion was administered first and the papers collected after about ten minutes. Item 2.2 was then administered followed by 2.1 again. The aim was to test the effect Item 2.2 would have on students to review their initial responses to Item 2.1.

After making them aware of their own misconceptions and discussing these with them in class, the student teachers were given an extended assignment to do a literature search and write a report (about three thousand words) on students' alternative conceptions on Newtonian mechanics. The class was next divided into groups of three, and each group allocated a topic on mechanics from the GCE 'O' level syllabus. The task was for each group to develop a teaching module grounded in constructivism. That was followed by each student doing a forty minute micro-lesson presentation on a topic from the unit allocated to his/her group. These two tasks constituted forty per cent of the total assessment for the second physics methodology course. Finally, a questionnaire was administered to the BScEd cohort at the completion of the two-semester long physics methodology courses. Its purpose was for student trainees to evaluate the various components of the two physics methodology courses. The students were asked to assess on a scale of 0 to 5 how useful they had found each component of the course.

With the provincial secondary school science teachers in PNG, data was obtained during school-based in-service programmes. At the beginning of the study mentioned above, these teachers had given lists of physics topics which they wanted the university researchers to run refresher courses on. The researchers were able to identify the teachers' alternative conceptions during in-service sessions. Test items were written on the board and the teachers were allowed to discuss their responses with the researchers. The researchers, without giving clues on right or wrong answers, would then teach the concept that was tested followed by re-administering and discussing the same test item. The teachers were then asked to write in their diaries whether the refresher course had helped them in gaining better understanding of the particular concept, and if so, they

were to show evidence(s) that they had actually understood the concept. Those diaries were read by the researchers after every in-service session. After a series of in-service courses, the researchers together with the teachers, developed, trialled, and evaluated teaching modules on physics topics that the teachers were teaching in their regular classes.

The test items

Item 1	A person jogs eight complete laps round a quarter kilometre track in a total time of 12.5 min. Calculate the average velocity in metres per second.
Item 2.1	During practice, a baseball player hits a very high ball, and then runs in a straight line and catches it at about the same height the ball was hit from. Which had the greater displacement, the player or the ball? Explain your answer.
Item 2.2	A football is kicked from the ground at an angle $\theta = 30^\circ$ with a velocity of 20 m s^{-1}. Calculate the time it will take the ball to hit the ground. (Ignore air resistance and take acceleration due to gravity, $g = 9.81$ m s^{-2}).
Item 3	A 50 and 10 cent coin were dropped simultaneously from the same height above a level floor. It took the 10 cent coin 2.5 s and the 50 cent coin 2.7 s to reach the floor. What do you think of the result?
Item 4	Which of the following statements are correct? i) Forces are to do with living things. ii) Constant motion requires constant force. iii) The amount of motion is proportional to the amount of force. iv) If a body is not moving there is no force on it. v) If a body is moving, there is force acting on it in the direction of motion.
Item 5	What is the acceleration of a car that maintains a constant velocity of 100 km h^{-1} for 10 s?

Data analysis and results

Results of the two studies involving UBD teacher trainees and the PNG science teachers have been reported in earlier works (Baimba and Agyeman, 1997; Brown and Baimba, 2004) and henceforth will only be referred to briefly in this paper.

Test Items 1 was analysed by determining the percentage of students who solved the problem using the physical definition of displacement. Of the 22 CLSSE teacher trainees who attempted this item, only four (18%) solved the problem correctly. The remaining 72% calculated average speed rather than average velocity. It is worth mentioning the fact that these students were taught by one of the authors who particularly stressed conceptual understanding. Test Item 2.1 was also analysed by calculating percentages of students who correctly interpreted the concept tested. Two out of the 22 CLSSE and five out of seventeen BScEd students demonstrated understanding by arriving at a scientifically sound conclusion, that both the ball and the player covered the same displacement. Flawed reasons from those who did not interpret the concept correctly were categorised. Students who believed that the ball covered the greater displacement gave one or more of the following reasons:

- more momentum or force is given to the ball by the player;
- the initial velocity of the ball is greater than that of the player;
- the ball went up and down covering greater displacement;
- the ball followed a parabolic path unlike the player, who ran in a straight line;
- if we extend the distance travelled by the ball into a straight line, it is larger than the distance travelled by the player.

The other group believed the player covered the greater displacement for one of the following reasons:

- the ball was back at its original position (same level) whereas the player was not at his/her original position;
- the motion of the player was constant while the motion of the ball varied from start to finish;
- the total displacement of the ball was zero as its displacement was cancelled out;
- the player covered a certain displacement because he did not go back to his original position.

Test Item 3 was analysed by breaking down the thinking or explanation put forward by the students for the difference in time. Five themes emerged and the percentage of students holding to each theme for the two cohorts that constituted the sample is contained in Table 1. Test Item 4 was also analysed by determining the percentages of students who agreed with each of the statements and the results are shown in Table 2.

For test Item 5, none of the twelve fourth year minor BScEd students or BEd/CLLSE students solved the problem correctly. One student approached the problem by using the equation $v = u+at$, and upon substitution, $100 = 0+10a$, got $a = 10\,\mathrm{m\,s^{-2}}$. Many

Explanation	4th year students (13 major/12 minor)	3rd year students
	Percentage ($N = 25$)	Percentage ($N = 50$)
Difference in time is due to bigger surface area of 50 cent coin	36	38
50 cent coin should fall faster because it is heavier	4	32
Answer is not correct because the two coins should fall at the same rate	12	10
Time difference is due to human error	32	16
10 cent coin should fall faster (the less the mass, the greater the acceleration, $F = ma$)	16	4

Table 1: Students' explanations for the time difference in Test Item 3.

others used the definition, acceleration = velocity/time and went ahead to substitute the data $u = 27.8$ m s^{-1}, $t = 10$ s to obtain $a = 2.78$ m s^{-2}.

Mean scores for students' rating of various components of the physics methodology courses are shown in Table 3. The highest mean of 4.46 (on a five point Likert-scale) was for the sub-scale C6 – review of research articles on students' alternative conceptions. Means scores for sub-scales C3, C4, C5 and C8 were also relatively high. Cronbach's alpha reliability for this scale was calculated as 0.56, which is acceptable (compared with the accepted value of 0.5) based on sample size and number of items on the scale.

Discussion and conclusion

The poor performance, particularly by the teacher trainees on those basic concepts in mechanics, though disturbing, is not surprising. Results from studies conducted from other parts of the world have shown that physics teachers hold alternative conceptions that are at variance with scientific ones (Hestenes, 1998). Such findings leave one won-

Statements (All are incorrect and conceptually flawed)	Percentage that agreed with statement (i.e. gave the wrong answer)		
	4th Year ($N = 25$)	3rd Year ($N = 42$)	BEd/Cert ($N = 33$)
Forces are to do with living things.	8	7	15
Constant motion requires constant force.	56	60	67
The amount of motion is proportional to the amount of force.	48	79	88
If a body is not moving there is no force on it.	8	43	15
If a body is moving, there is a force acting on it in the direction of motion.	76	64	82
Students who recognised that all the statements were incorrect.	8	12	0

Table 2: Percentage of students agreeing to incorrect statements about force and motion.

dering what has been the effect of the numerous results from PER on physics education in general. About two decades ago, emerging teaching and learning theories grounded in constructivism gave false hopes to many educationists. At that time some people thought conceptual change would be easy to grasp. It is only beginning to dawn on some researchers that alternative conceptions are erroneous and persistent and are not easily modified even by the most effective teaching strategies.

Researchers have studied conditions under which students become convinced to replace non-scientific notions with scientific ones (Posner, Strike, Hewson and Gertzog, 1982; Guzzetti, Snyder, Glass and Gamma, 1993). According to Hewson and Hewson (1984), if concepts to be learnt are counterintuitive, students can reject the information, memorise the information, or reconstruct existing knowledge so that it changes (conceptual change). Results from this study and similar ones undertaken by the researchers (Baimba and Brown, 2003) make us believe that very little if any conceptual change

	Unit	Mean (σ)
C1	Aims and objectives of science education	3.23 (1.013)
C2	Nature and philosophy of science and science education	3.07 (0.862)
C3	Methods of teaching science	4.53 (0.519)
C4	Laboratory organisation and management	4.07 (1.115)
C5	Lesson planning	4.15 (0.800)
C6	Review of research articles on students' alternative conceptions in physics	4.46 (0.776)
C7	Concept mapping	3.76 (1.012)
C8	Development and production of curriculum materials (unit plans, teaching modules)	4.30 (0.854)
C9	Assessment in science education	3.85 (1.281)

Table 3: BScEd students' evaluation of various components of the Physics Methods courses ($N = 60$).

takes place during the formal teaching of physics. What takes place when students are taught physical concepts that are counter to their intuitive notions is conceptual accommodation. Rather than changing prior conceptions, students accept the new information but store it in a schema that is dormant, only recalling it when required such as in doing assignments or during examinations. At other times, they resort to intuitive notions in explaining physical concepts.

To elaborate, displacement is a scientific concept introduced to students when they start the study of kinematics in physics. To a great extent, the concept runs counter to everything the student has learnt about distance in relation to movement of bodies. Hence, the notion that a body that has traversed a great distance can have zero displacement is accepted like religious dogma. This explains why the majority of the sample calculated average speed for Test Item 1, or failed to transfer the physics principle they

would normally apply solving numerical problems on parabolic motion to correctly answer Test Item 2.1. Similarly, the same argument holds, explaining why even the BScEd third and final year students unconsciously could not recall the scientific explanation that gravity pulls objects towards earth at the same constant, accelerating rate. The erroneous reason that the larger coin will fall faster superseded scientific concepts which the students have been taught (e.g., effect of air resistance on freely falling bodies). In the same vein, the definition of force as a push or pull nicely fits everyday mental schema. So too does the corollary colloquial concept of pushing and pulling as something one does which necessary causes motion (an Aristotelian physics notion). Little wonder then that student teachers as well as practising teachers, even after being taught the concept, find it difficult to realise that the resultant force on a body moving with constant speed is zero.

It follows from the above analyses that textbook and lecture-driven programmes are not helping the majority of physics teacher trainees to alter their intuitive conceptions. The high mean score of 4.46 for sub-scale C6 in Table 3 is a testimony to this. The BScEd cohort reported that doing the literature search on students' alternative conceptions in physics made them for the first time come to terms with how little they themselves understood Newtonian mechanics. They rated that component of the two-semester long physics methodology courses as the most rewarding one. This leads to the conclusion that teaching for conceptual change, particularly those ideas to do with intuitive notions, requires a more holistic approach and deeper theoretical understanding than we have realised before. Aranzabal (2005) quotes Duschl and Hamilton (1998) and Izquierdo, Sanmarti and Espinet (1999), as stating that conceptual change cannot happen if we only take into account preconception; this must be accomplished by deep methodological, axiological and ontological changes instead. Aranzabal (2005) noted that scientific changes or revolutions do not only transform the old theory but also change ways of seeing the world (ontological component), the forms of reasoning (epistemological component), the methods (methodological component) and in the values and aims of the new theory (axiological). He further argues that the transition from an accepted theory to a new one is gradual. This, according to him, is due to the fact that the theory to be modified has to its credit many successful results and the existence of stages of partial modifications whereas a new theory that promises good results is at first only tentatively explored.

Accomplishment of the methodological and other components cannot be left in the hands of teachers alone. For example, to promote better conceptual understanding in physics requires new textbooks that recognise the importance of embedding teaching in rich context, as well as paying attention to research in conceptual development. According to Kuhn (1962), textbooks are pedagogic vehicles for the perpetuation of normal science, and the normal science in many current university and secondary school physics textbooks lack these ingredients. There are already moves in this direction, and work by Paul Hewitt (*Conceptual Physics*), Lillian C. McDermott (*Physics by Inquiry*), and others, are commendable but much remains to be done. Furthermore,

present physics curricula that seem to overemphasise mathematical formulation of a topic at the expense of the imagination required to establish it, and the appropriate evidence to support it (Stinner, 1994), need to be revised. The new thinking is that physics teaching should help students develop the ability to reason qualitatively about physical processes, structure that content into coherent and approximately organised and appropriately accessible mental models, and learn to apply that model to physics in an expert and creative way (Redish, 1994). The few conditions listed above are beyond the attainment of current physics teachers or teacher trainees who themselves went through textbook-centred lecture-driven programmes. This calls for restructuring of pre-service physics teacher education programmes as well as outreach programmes by university physics educators to assist serving teachers.

If the desire is indeed to promote better conceptual understanding in physics at the secondary level, then the role of university physics educators should not end at certification ceremonies. The work we did in PNG made us believe that science (physics) teachers feel isolated and there are times when they genuinely need help. The school-based in-service component of that study resulted in (i) bridging the knowledge gap between what the teachers know and what they teach, (ii) the teachers overcoming their fear of using scientific equipment, and (iii) developing positive attitudes to teaching (Baimba and Agyeman, 1997). In a recent workshop organised by the Brunei Association of Science Education, one physics teacher had this to say, 'The physics I studied at university is not the physics I am teaching at secondary school. We need the university to organise more workshops in physics, regular training in physics experiments and a regular supply of research papers'. There is no better way of stating what secondary physics teachers' expectations are of university physics educators than what this teacher so eloquently expressed. The benefits of such collaborative work between university physics educators and teachers are enormous for the advancement of better teaching and learning of physics at the secondary school level.

References

AMEH, C. O. AND GUSTONE, R. F. (1985). *Research in Science Education*, **15**, 151–157.

ARANZABAL, J. G. (2005). *The implications of physics education research on the teaching at high school and university* [online].
Available from: http://wwwsi.unian.it/educa/inglese/jennar-i.html

BAIMBA, A. A. AND AGYEMAN, K. (1997). The role of university physics departments in improving the state of physics education at pre-tertiary level: A Papua New Guinea case, in A. Z. Tajuddin, I. A. Jalal, J. Jantan, K. M. Salleh and Z. A. Wahab (Eds) *University physics education for the twenty-first century* (pp. 33–40). AsPEN: Malaysia.

BAIMBA, A. A. AND BROWN, D. P. (2003). Physics teacher trainees' conceptions and

understanding of selected concepts in mechanics and electricity, in H. R. Dhindsa, B. E. Lim and M. A. (Ken) Clements (Eds), *Studies in science, mathematics and technical education* (pp. 21–28). Universiti Brunei Darussalam: Gadong.

BROWN, D. P. AND BAIMBA, A. A. (2004). Pre- and post-reflections on teaching practice of science teacher trainees, in I. P.-A. Cheong, H. S. Dhindsa, A. Kyeleve and O. Chigu (Eds), *Globalisation trends in science, mathematics and technical education* (pp. 270–279). Universiti Brunei Darussalam: Gadong.

CHINN, C. A. AND BREWER (1993). The role of anomalous data in knowledge acquisition: A theoretical framework and implications for science instruction, *Review of Educational Research*, **63**(1), 1–49.

ENOCH, L. G. AND GABEL, (1984). Pre-service elementary teachers' conceptions of volume, *School and Mathematics*, **84**(8), 670–680.

GUZZETTI, B. J., GLASS, T. E., AND GAMAS, G. V. (1993). Meta-analysis of instructional interventions from reading education and science education to promote conceptual change in science, *Reading Research Quarterly*, **28**, 116–161.

HAKE. R. (1998). Interactive-engagement versus traditional methods: A six-thousand student survey of mechanics test data for introductory physics courses, *The American Journal of Physics*, **66**(1), 64–74.

HESTENES, D., WELLS, M. AND SWACKHAMER, G. (1992). Force concept inventory, *The Physics Teacher*, **30**(3), 141–158.

HESTENES, D. (1998). Who need physics education research?, *The American Journal of Physics*, **66**(6), 465–467.

HEUVELEN, A. VAN (1991). Overview, case study physics, *The American Journal of Physics*, **59**(10), 898–907.

HEWSON, P. W. AND HEWSON, M. G. (1984). The role of conceptual conflict in conceptual change and design of science instruction, *Instructional Science*, **13**, 1–13.

KRUGER, C. (1990). Some primary teachers' ideas about energy, *Physics Education*, **25**(2), 86–91.

KUHN, T. (1962). *The structure of scientific revolutions*. The University of Chicago Press: Chicago.

LIGHTMAN, A. AND SADLER, P. (1993). Teacher prediction versus actual student gains, *The Physics Teacher*, **31**(3), 162–167.

MCDERMOTT, L. C. (1984). Research on conceptual understanding in mechanics, *Physics Today*, **37**(7), 24–32.

MCDERMOTT, L. C. (1991). Millikan Lecture 1990: What we teach and what is

learned: Closing the gap, *The American Journal of Physics*, **59**(4), 302–315.

MCDERMOTT, L. C., SHAFFER, P. S. AND CONSTANTINOU, C. P. (2000). Preparing teachers to teach physics and physics science by inquiry, *Physics Education*, **35**(6), 411–416.

NIEDDERER, H. BERTHGE, T. MEYLING, H. AND SCHEKER, H. (1992). *Epistemological beliefs of students in high school physics*. Paper presented at NARST, Boston.

OSBORNE, J. AND FREEMAN, J. (1989). *Teaching physics: A guide for the non-specialist*. Cambridge University Press: Cambridge.

POSNER, G. J., STRIKE, K. A., HEWSON, P. W. AND GERTZOG, W. A. (1982). Accommodation of a scientific conception: Toward a theory of conceptual change, *Science Education*, **66**, 211–227.

REDISH, E. F. (1994). Implications of cognitive studies for teaching physics, *The American Journal of Physics*, **62**(9), 796–803.

STINNER, A. (1994). Providing contextual base and a theoretical structure to guide the teaching of physics, *Physics Education*, **29**(6), 375–381.

STINNER, A. (2003). Scientific method, imagination, and teaching science, *Physics in Canada*, **59**(6), 335–346.

Computing

Online learning resource: A Canadian case study that may suit the Middle East

Riadh W. Y. Habash,[1] Christine Suurtaam,[2] Hafid T. Alhafid,[3] Mustapha C. E. Yagoub,[1] Karima Kara[4] and Ghanim Ibrahim[1]

[1] *School of Information Technology and Engineering, University of Ottawa, Ottawa, Canada*
[2] *Faculty of Education, University of Ottawa, Ottawa, Canada*
[3] *College of Engineering and Applied Sciences, Al Ghurair University, Dubai, United Arab Emirates*
[4] *e-Learning Centre, University of Ottawa, Ottawa, Canada*

The use of the Internet and its learning capabilities is growing rapidly as a dynamic and engaging learning environment that offers the potential for creating exciting learning opportunities for students. In recognition of the above, an online foundation/bridging resource has been developed at the University of Ottawa in Canada. We expect that this resource will serve as a tool to give students a level of learning sophistication and knowledge expected of them at the upper secondary, foundation/pre-university level, and the early years of university studies. Based on the above experience, we believe that the use of online education in the Middle East for prospective and beginning university students may provide an alternative way to address the challenges in teaching meaningful content and complement the traditional lecture format.

Introduction

Students moving from secondary schools to mathematics-related programmes at universities, such as engineering, often have difficulty applying their mathematical knowledge to new situations. They find that there are gaps in the knowledge and skills expected of them in a university programme. Usually, these university programmes depend critically on students' experiences of learning mathematics and on their ability to make connections between the mathematics they learn in secondary school and the practical situations presented later at university.

Technology may play a key role in making the connection to mathematics, science, and engineering applications in a variety of ways. Internet-powered learning environments provide increased access to learning resources. Promising Internet-based learning is possible when mathematics, foundations of engineering, and human-computer interaction design experts work together and take into account sound pedagogical practices.

This paper is divided into two parts. In the first part, we discuss briefly the details of a unit of online learning resource currently under development at the University of Ottawa in Canada. The unit is a module that involves constructing models of electric circuit elements and interconnecting them to form electric circuit models of practical systems. In the second part, we discuss the implementation of online education, with special emphasis on the Middle East, taking into consideration the Canadian example and its influence on students at Al Ghurair University in the United Arab Emirates (UAE).

Engineering learning resource: The Canadian case

With the explosion of the Internet and the desire of many institutions to disseminate courses across the world, many students look to online education with promise (Hong, et al., 2004). To help address the needs of the many students who are joining or already completing first year engineering, the Faculty of Engineering worked with the Faculty of Education to develop an Internet portal Engineering Learning Resource (ELR) with Essential Math.[1] The portal is an online resource with many units which are administered via the Internet. We have developed the first unit of the resource as a pilot project to be followed by other units that cover various subjects in engineering sciences with essential mathematics. The first unit is related to the modelling of electric circuit elements. It compromises thirteen topics. Each topic includes a number of special features designed to make learning easier and to let students explore the subject matter in greater depth, if desired. The complete list of topics covered in the unit is as follows: charge and Coulomb's law; electric current; voltage; resistance; ohm's law; power and energy; elements of electric circuits; Kirchhoff's laws; series circuits; parallel circuits; analysis of combination circuits; capacitance; and inductance.

The unit provides several resources and professional development activities which are designed to give learners and teachers technical competence in implementing modelling activities. The following is a list of the resources: system of units; brief profile of early history of electrical engineering; practical applications of electrical circuits; analogy between a water pipe and a resistor in an electric circuit; categories of electrical quantities; standard colour code system and Ohm's law charts; summary of main electrical concepts; end-of-unit problems; and multiple choice questions.

Some of the technical options considered for the resource included HTML only; HTML synchronised with audio; and flash animations. HTML with audio and anima-

[1] See `http://www.site.uottawa.ca/mathasatool`

tion results in presentations that can be streamed over slow Internet connections yet remain quite attractive. Providing an Internet-based learning resource must have a means of two-way communication. Current options available for such interaction include e-mail and newsgroups although many other modes of interactivity are possible.

The authors of the article prepared the content of the unit. They found that the process of developing the content far exceeded the time required for developing a traditional university course. As preparation time can be a serious obstacle to creating quality online material, the authors recommend that faculty and/or online course developers ensure they set aside sufficient time for the process.

Online education

Information and communication technologies have been rapidly developing on a worldwide scale, bringing new innovations to teaching and learning. In developed countries, such technologies are being introduced through online courses and distance education in government, business, and education. Meanwhile, in developing countries including the Middle East, efforts are underway to introduce these technologies into the educational system.

The development of online education is one of the challenges for higher education providers in the future, especially in developing countries. New pedagogical solutions and innovative learning and communication techniques have to be developed to make online education an attractive, open, and useful facility. Also, the question of access to technology has to be resolved within a given country and between the developed and developing countries.

The increase of online education may provide opportunities for widening access and study possibilities in higher education for under-privileged groups in societies, as well as under-privileged societies as a whole, given the current state of the Internet and technical delivery mechanisms. Online education may also be continuously and quickly upgraded in both academic content and technological solutions. This is important in an era where education becomes more and more dynamic and continuous.

Delivery of courses may be provided both as partly traditional, partly online, as well as completely online by higher education institutions operating under the public regulations either individually or in co-operation with other universities and with private providers. Online education can be provided both locally, regionally, and nationally as well as globally. This varied field of learning complicates the role of online learning in the benefiting societies and calls for responsible implementation of higher education policies related to online education both by the authorities as well as higher education institutions providing online courses.

The cost of delivery of online courses is comparable to on-campus education (Bourne et al., 2005). However, online learning must not be considered as a means to cut the cost of higher education. Increasing provision of online education must not turn into an excuse for governments to evade their responsibility of providing higher education to

all those who desire it. Also, the costs of online learning must not fall upon students. In the case of national schemes, a given government must provide higher education institutions with adequate resources for implementing online education policies. Finally, full or partial online programmes will, in full operation, be substantially cheaper to run than conventional campus learning.

In the developed world, it has become a challenge for each individual to keep technically up-to-date. We may therefore expect that most important areas of operation will be within continuous education. Student recruitment to online learning will therefore initially be dominated by young professionals.

The main disadvantage of online education is the social connectivity between students, and between students and teachers, and is a determining factor in whether people learn well online (Richardson et al., 2003). Although it is still widely believed that even the most interactive online experience can never replace the face-to-face learning experience, online communications via e-mail, mailing lists, and discussion boards or chat rooms may remove some of the social barriers between student–teacher and student–student interactions.

Some of the special needs of education have not been well served by methods of online education, specifically laboratories, mathematical foundations, and design tools (Bourne et al., 2005). Laboratories are notably difficult to provide online because of the traditional desire for direct operation of equipment. Also, difficulties exist while developing courses that require mathematical equations, computing power, and graphics that are not always available in distributed networked environments.

Blended learning, which is an optimal combination of face-to-face and online education, can be considered as a best possible approach that improves learning and gains the satisfaction of teachers and students at reasonable cost (Bourne et al., 2005). We too believe that online learning does not substitute on-campus teaching but complements it.

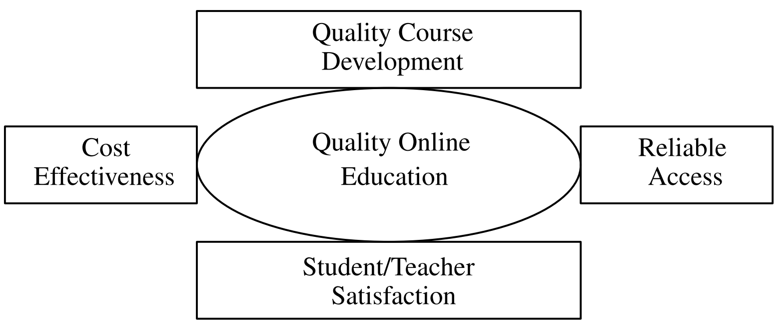


Figure 1: The main components of online education.

Discussion

Online education for first year and prospective university students provides an alternative way to address the challenges in teaching. Figure 1 shows the main components of online education. In previous years, problems in access in some Middle Eastern countries were largely due to lack of Internet connectivity; such problems have however been solved within the region in recent years. Meanwhile, the cost of developing and delivering online material has decreased over time and is currently comparable to on-campus learning. Importantly, the need for good course developers, probably a combination of good educators and instructional and digital art designers, has been on the rise.

Being an ultimate goal for any academic institution, student satisfaction has always played an important part in any institutional and curricula development activity, especially in countries where academic accreditation is either legally enforced or at least considered an added competitive advantage. Student satisfaction has been addressed in three surveys conducted at the University of Ottawa (Habash et al., 2005). At Al Ghurair University in the UAE, a group of twenty students from Computer Science and Engineering (CSE) and Electrical and Electronics Engineering (EEE) were individually surveyed to evaluate the components of the Canadian ELR after attending a presentation describing the main features of the resource. As shown in Table 1, between 45% of students see ‘mathematics’ and ‘engineering’ as a way to solve problems and as a tool for everyday life. Students showed great interest in taking a course with an online component. Also, the cohort seemed evenly split between being self-motivated on the one hand and requiring some sort of help to enhance their motivation on the other.

Finally, the resemblance between University of Ottawa and Al Ghurair University students’ perspectives is remarkable, especially considering the value of ‘mathematics’ and ‘engineering’ in life. Students of both universities have also indicated strong interest in having a course with an online component. The reasons behind this resemblance may be the strong similarities in the level of computer and Internet penetration in both institutions. Furthermore, both institutions carry common North American educational values since Al Ghurair University students follow a curriculum which is based entirely on a North American model.

What would best describe the way you see mathematics?		
	No.	%
A tool for everyday life	9	45
A set of rules and procedures	6	30
An abstract game	2	10
A way to solve problems	13	65
A tool for science/engineering	9	45
A form of language	1	5
A way of explaining the world	6	30
What would best describe the way you see engineering?		
A tool for everyday life	9	45
A set of rules and procedures	8	40
An abstract game	1	5
A way to solve problems	9	45
A scientific tool	9	45
A form of language	2	10
A way of explaining the world	9	45
What would best describe your interest in taking an online course?		
I am very interested in taking a course with an online component	5	25
I am somewhat interested in taking a course with an online component	10	50
I would prefer taking a course that is not online	5	25
What would best describe your personal motivation and self-discipline?		
I feel proud that I can motivate myself to achieve my goals	11	55
I sometimes need the help of my friends to encourage me	7	35
I often need guidance/supervision to achieve my goals	5	25

Table 1: Survey responses of twenty students from Al Ghurair University, UAE.

References

BOURNE, J., HARRIS, D. AND MAYADAS, F. (2005). Online engineering education: Learning anywhere, anytime, *Journal of Engineering Education*, **94**(1), 131–136.

HONG, P. S., ANDERSON, D. V., WILLIAMS, D. B., JACKSON, J. R., BARNWELL, T. P., HAYES, M. N., SCHAFER, R. W. AND ECHARD, J. D. (2004). DSP for practicing engineers: A case study in Internet course delivery, *IEEE Transactions on Education*, **47**(3), 301–310.

HABASH, R. W. Y., SUURTAMM, C., YAGOUB, M. C. E., KARA, K. AND IBRAHIM, G. (2005). Online learning resource for smooth transition from high school to engineering education, *IEEE Transactions on Education* (in review).

RICHARDSON, J. C. AND SWAN, K. (2003). Examining social presence in online courses in relation to students' perceived learning and satisfaction, *Journal of Asynchronous Learning Networks*, **5**(1), 68–88.

Multimedia-based effective learning strategies: A case study

M. V. N. M. Ramakrishna Kumar and Venkateswara Sarma Mallela

Department of Electronic and Computer Engineering, Caledonian College of Engineering, Seeb, Sultanate of Oman

A case study on self-learning tutorials using Macromedia Director software for learning Photoshop and Premiere as computing tools is presented. Microsoft Word based self-learning tutorials are also developed and described. Results in terms of the effectiveness of such self-learning tutorials for a selected class of students are presented and discussed. The strategies presented can be applied to either upper secondary or lower-tertiary-level settings.

Introduction

Relentless technological advancement, and its corresponding availability at affordable cost, has meant that the use of computers and computer-based multimedia software have become an integral part of our lives. Educators today play a vital role in initiating multimedia-based learning in the technological classroom with multimedia-based learning strategies, in particular, becoming increasingly popular the world over at all levels of education. For us, multimedia has proved to be effective in enhancing the learning skills at all levels of education. Moreover, the present day digital environment (Abernethy and Allen, 1998), which encompasses practically every walk of our day-to-day lives, demands the knowledge of a multimedia environment. To name but a few, present day audio and video has become an integral part of music, news channels, student projects, medical diagnosis and surgeries, business and advertisements. Our goals as educators should therefore include equipping our students with problem-solving, communication, teamwork, self-assessment, change management, and lifelong learning skills. All such goals are centred on student learning.

Computing techniques in multimedia play an important role in effective learning at an enhanced rate. Broadly speaking, the prerequisite to multimedia learning is a proficiency in the Information and Communication Technologies (ICTs) as the principal

computing tools used in multimedia include Power Point, Adobe Premier and Photoshop, Microsoft (MS) Word, Macromedia Flash, Macromedia Director, Ulead Video Studio, and Camtasia.

Self-learning tutorials (Whiteley, 2005) play an important role in effective learning strategies and require the student to be familiar with various computing tools. On the whole, after completing secondary education, most students enter our college at the pre-engineering (foundation) level. Certain, specific, self-learning tutorials have been designed with the needs of these particular students in mind. These self-learning tutorials help the student to work with various multimedia computing tools which form part of the ICT assessment programme.

In this paper we present case studies that are representative of a multimedia-based effective learning approach. A number of students were given these tutorials and their performance was analysed to assess the effectiveness of the self-learning tutorial approach. The analysis of the case studies indicate that the students were able to grasp the basic computing techniques used in multimedia, and apply them directly to practical problems, thereby enabling them to keep abreast of current state-of-the-art technology.

Relevance of ICT skills and their importance

ICTs are used to teach the student the knowledge and skills they will require in the twenty-first century. ICT can support, enhance, and extend the learning potential of the student. The purpose and value of ICT skills need to be instilled in order to promote a readiness to learn (Selinger, 2001). The student needs to become familiar with basic ICT skills, even at the secondary level, if they are to cope with the technological necessities they could expect to encounter throughout their academic lives and beyond.

Broadly speaking, the basic domains within which ICT skills fall include:

- searching for information – Library and the Internet;
- using a computer for writing – Word processing;
- using a computer for communicating – Electronic mail;
- using a computer for numerical calculations – Spreadsheets.

Hands-on experience in basic ICT skills is therefore imperative if a student is to progress beyond the most rudimentary of levels.

Computing tools for self-learning tutorials

Self-learning tutorials using multimedia computing and application tools are developed for use by the students so that they may learn by themselves. Several tutorials were developed for use with various cohorts of students that involved the use and practice of various multimedia computing tools like Adobe Premiere, Adobe Photoshop,

Macromedia Flash and MS Word. These tools facilitate the use of various skills such as editing, morphing, designing, adding title effects, and so on.

Adobe Premiere

Adobe Premiere (Droblas and Greenberg, 2003) provides a complete editing environment to create and deliver professional, polished videos. It also provides the widest range of video hardware support, including the Sony DVCAM, and other company devices. It allows the editors to customise their work-flow to suit their requirements. Editors can instantly view effects, titles, and transitions as they are made. In addition, video editors can enhance their projects with broadcast quality title sequences created in the new Adobe Title Designer. With more than one hundred pre-designed templates and typographical controls, including outlined text, leading, and kerning, users can quickly create eye-catching results. It delivers complete, affordable video editing tools for producing professional-quality video for DVD, videotape, Web, CD-ROM and film. The basic features that are routinely used with this package are shown in Figure 1.

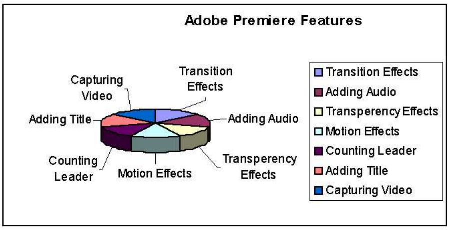


Figure 1: Adobe Premiere features.

Adobe Photoshop

Adobe Photoshop is the premier photo editing software tool. Photoshop can be used to enhance images for webpages, Power Point presentations, or for documents to be printed. This tool facilitates learning in image file types, cropping images, compositing (putting several images together), ghosting images (for use as webpage backgrounds), using layers, creating masks, applying filters, and formatting text with bevels and other effects. The basic features that are generally used in this package are shown in Figure 2.

MS Word

MS Word is a word processing tool widely used (in many languages now) for the writing of essays, reports, lab work, theses, dissertations or any other text-based document. Word processing programs allow features like entering and editing text and adding

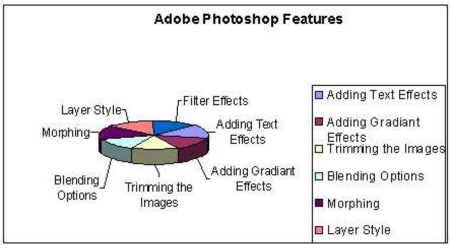


Figure 2: Adobe Photoshop features.

graphics and pictures from other programs. In addition, MS Word provides comprehensive drawing features that are extremely useful. Web pages can be created and previewed in MS Word. Some of the features that are generally used in this package are shown in Figure 3.

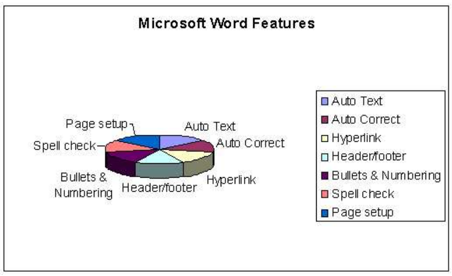


Figure 3: Microsoft Word features.

Development of self-learning tutorials

Multimedia-based self-learning tutorials were designed and developed using Camtasia software for teaching MS Word as part of an ICT skills programme at our institution. These are planned to be extended in the future to spreadsheet and e-mail programs. This new word processing package has been integrated with already existing Adobe Premiere and Photoshop software, thus giving the student another option.

Some screen shots from the MS Word self-learning tutorials developed are shown in Figure 4.

Figure 4: Self-learning tutorials splash screens that are used in the college.

Figure 5: Microsoft Word self-learning tutorials screen shots that are used in the college.

Case studies

The students were given several projects using the self-learning tutorials and the computing tools. Some of the projects that were done by various students, using various computing tools, are shown in Figure 6.

Being representative of the case studies performed, for the purpose of this paper, the following projects were selected for detailed analysis:

- Eye Pod Poster
- Smart Kitchen Device
- FutureTech Integrated System

Eye Pod Poster: The purpose of this project was to build a conceptual e-device that could be used at home by anyone of any age. It was required to support home-networking and communication technologies (see Figure 7).
Main Tools used: Adobe Photoshop, Fire Works.

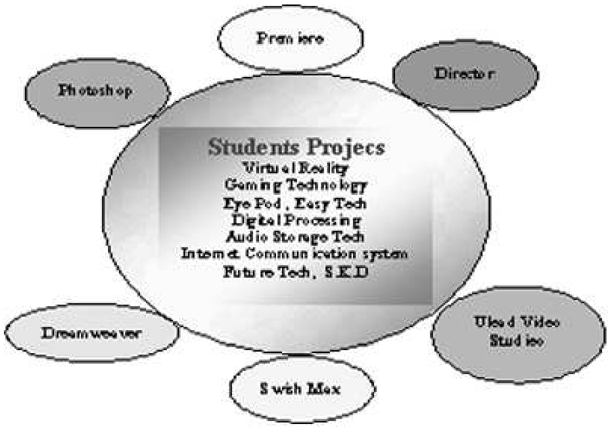


Figure 6: Case studies.

Features used for the poster: Layer effects, bevel and emboss options, title effects, filter effects, and gradient effects.

Figure 7: Eye Pod Poster (Semle, Semle, Singh and Zadjalli, 2004).

Smart Kitchen Device: In this project, the task was to design a device which would help or simplify life for the user in the kitchen. The Smart Kitchen Device (SKD) aims to integrate the latest technologies, such as a touch screen, Internet connection, LCD screen, Bluetooth technology, USB port, and a microwave transmitter/receiver which was to form the main component of the SKD device (see Figure 8).
Main Tools used: Adobe Photoshop, Macromedia Flash.

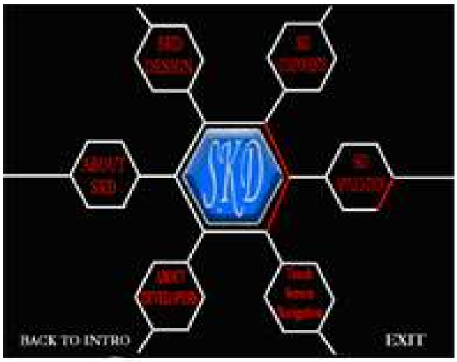


Figure 8: Smart Kitchen Device (Ahlam, Nasreen and Ruqaya, 2003).

Features used for the simulation: Motion tween, shape tweening, layer effects and action scripting.

FutureTech integrated system: FutureTech Integrated System (FIS) is an extended laptop that augments the efficacy of current laptops. FIS hopes to set a standard for future laptops. Multiple technologies like video with night vision, high quality audio, tracking system, backup charger, active protection and fingerprint protection were all incorporated into the laptop (see Figure 9).

Main tools used: Adobe Photoshop, Macromedia Flash, Fireworks, Swish, Trendy Flash Intro Builder and Adobe Premiere.

Figure 9: FutureTech Integrated System (Dcruz, Al Kalbany and Nambiar, 2005).

Another interesting creative work done by one of our students, using Adobe Photoshop exclusively, involved features like morphing, filter effects, emboss effects, title effects and layer effects (see Figure 10). It may be seen that picture ‘e’ is generated using individual pictures superimposed with the indicated features. A histogram depicting the percentage of features used is shown in Figure 11.

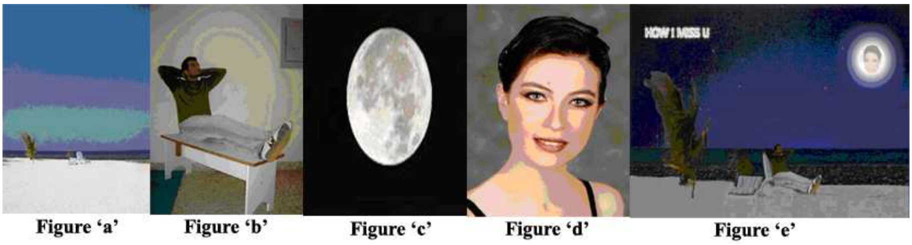


Figure 10: Sample project work (Saba, 2004).

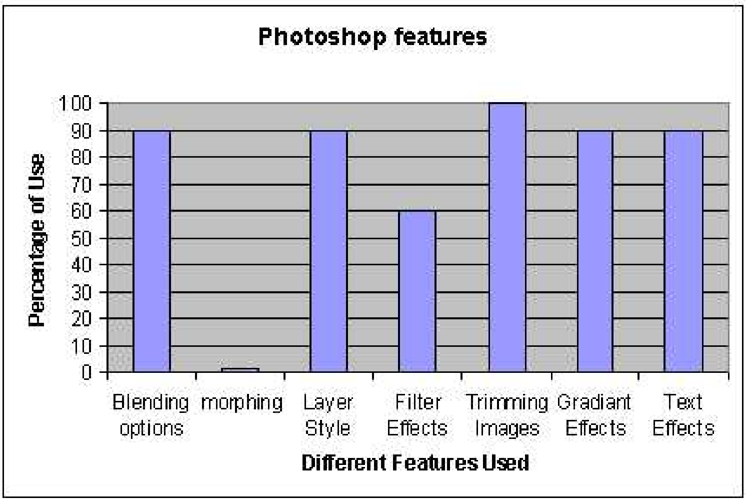


Figure 11: Adobe Photoshop features.

Effectiveness study

Students at our college since 2002 have been trained in basic ICT skills and effectiveness of self multimedia application packages, which included the self-learning tutorials. They were asked to do projects in specific areas using their skills learnt. For the purposes of analysing the effectiveness of the self-learning tutorials, the cases were monitored using various cohorts of students. Sixty students enrolled into a multimedia technology module in 2003–04. All students were exposed to packages with and without self-learning tutorials and were given certain specific projects on multimedia and applied graphics. Two options were given to the students, via Macromedia Director (without self-learning tutorials) and Adobe Premiere, Adobe Photoshop, Macromedia Flash (all with self-learning tutorials) to use for the projects. It was found that the majority of students (90%) were able to complete their projects when using multimedia packages that included the self-learning tutorials with little outside assistance. Interestingly, only 10% chose to use those multimedia packages without self-learning tutorials. Furthermore, students' output, in terms of report preparation, poster preparation, animation, simulation, oral presentations, self-confidence, and time taken to complete each assigned task, were closely monitored by the module leader and module tutors (see Table 1).

Parameter monitored	With self-learning tutorials	Without self-learning tutorials	Remarks
Time taken	Less	More	Less by 30%?
Elegance	Very good	Good	
Flexibility	More	Less	
Animation	Very good	Good	
Simulation	More relevant	Relevant	
Tutor's assistance	Less	More	Less by 25%?
Video and audio quality	Excellent	Good	
Editing work	Excellent	Good	

Table 1: Summary of the qualitative advantages found with using self-learning tutorials.

Conclusion

Based on the study described, the following conclusions can be drawn:

1. Self-learning tutorials improved learning outcomes, thus making the students responsible for their own learning.

2. Communication, co-operation and interpersonal exchanges among student groups were improved, thus enhancing their self-confidence.

3. The module leader and module tutor were able to broaden the scope of coverage within a subject using the same available time.
4. Students acquired critical thinking skills for self-directed learning.
5. Hands-on experience was gained by the student in working with current, state-of-the-art multimedia technology, thereby increasing their future employability.
6. The process is downwardly adaptable to the secondary level.

Acknowledgements

The encouragement and support provided by the Caledonian College of Engineering (which is affiliated to Glasgow Caledonian University, UK) is gratefully acknowledged. Useful discussions held with our colleagues Mr Sukhjit Singh and Mr Mohammed Hidayath Ali Baig are also duly acknowledged.

References

ABERNETHY AND ALLEN (1998). *Digital domain*. PWS Publishing Company.

AHLAM, NASREEN AND RUQAYA (2003). *Smart Kitchen Device*. Unpublished. Caledonian College of Engineering: Seeb.

DCRUZ, D., AL KALBANY, A. AND NAMBIAR, A. (2005). *FutureTech Integrating System*. Unpublished. Caledonian College of Engineering: Seeb.

DROBLAS, A. AND GREENBERG, S. (2003). *Adobe Premiere 6.5 Bible*. Wiley: Dreamtech, India.

SABA, A. (2004). *Sample Project Work*. Unpublished. Caledonian College of Engineering: Seeb.

SELINGER, M. (2001). *Journal of Information Technology for Teacher Education*, **10**(1-2), 143–152.

SEMLE, A., SEMLE, A., SINGH, S. AND ZADJALLI, Z. (2004). *Eye Pod Poster*. Unpublished. Caledonian College of Engineering: Seeb.

WHITELEY, S. (2005). *Accelerated learning online: Helping you learn faster* [online]. Available from: `http://www.accelerated-learning.com/`

MS Access inquiry lesson: A classroom research project

Rizik Al-Sayyed and Khalil Khalil

University General Requirements Unit, United Arab Emirates University, Al Ain, United Arab Emirates

Reflective teachers develop insights into their students' learning through observing their performance and achievements. These teachers analyse student performance in class, identify potential problems, try to modify their teaching practices, and then evaluate their results. Some ideas work out, but others do not. This research is intended to describe a mini classroom-based experiment conducted on two level 2 classes in the Information Technology programme at the United Arab Emirates University in order to reflect on the teaching–learning process adopted in these classes and to provide a better understanding of its effect on student performance in general.

Introduction

In an effort to examine the teaching–learning strategies practised in the Information Technology (IT) programme of the University General Requirements Unit (UGRU) at the United Arab Emirates University (UAEU), many questions have arisen. Among these, one particular question of significance to our teaching and learning process concerned the impact of using inquiry lessons on student understanding when introducing filters.

In beginning, we need to define what is meant by an 'inquiry lesson'? After reviewing the literature, an inquiry lesson is briefly one which is conducted when students are asked to work on an activity through which they discover and test their own knowledge about a certain topic. During such a class, the teacher's role is no longer to provide direct instructions, but to choose a task and to provide guidance to the students as they explore their own understanding. Available research in this field has shown that an inquiry lesson could lead to better comprehension of the subject material under discussion since it is consistent with a teaching learning theory known as the constructivist model (Brooks and Brooks, 1993; Jaworski, 1998; Matthews, 1998).

Researchers have identified many characteristics of a constructivist classroom (see, for example, Brooks and Brooks, 1993). Highlighting those characteristics which are

antithetical with the traditional teacher-based methods adopted in some classrooms one has:

- The curriculum is presented as a whole, which is later broken down into parts with emphasis on main concepts.
- Following up student questions is highly valued.
- The teacher interacts with his/her students in an attempt to test the waters and elicit information.
- Evaluation of a student's learning is continually carried out during the class through teacher observation.

The experiment

Two level-two sections in the IT programme at UGRU, UAEU studying MS Access as part of the Fundamentals of Information Technology 2 (IT2) course were chosen to test the effects the two different teaching styles would have on student achievement.

Traditional step-by-step method

In a fifty-minute class of nineteen students, the topic of MS Access filters was introduced following the traditional step-by-step method. During the lesson, needed instructions were provided to solve some examples with the students. On that day, the students demonstrated their understanding of the material by solving questions; about fifteen of them were able to solve all the in-class practice worksheet (see Appendix A). A rather more difficult set of questions were handed out (see Appendix B) on the following day; it was however found that only six students from the nineteen were able to solve this set. The students were assisted in solving the second worksheet, but were not allowed to take notes or write down answers. Afterwards, a chance to have a second look at their class work was given, which led to fourteen of them being able to comprehend the issue under discussion and solve the questions.

It was concluded that this particular section depended heavily on the provision of direct teacher instructions which, if still fresh in students minds, would lead to solving the problems assigned on the worksheet. After a while, a revision of what needed to be done or remembered became an urgent must, subsequently confirming the aforementioned conclusion. Such a situation, therefore, paved the way to question the current teaching method adopted, and called for a thorough search for a substitute that would have a lasting effect on the students' learning as well as achievement.

Constructivist method

Being a unit that serves other entities at the university, UGRU has always stressed the importance of continuous evaluation of the different teaching methods adopted to

accomplish its mission in laying a solid foundation for the first year student. As is the case, the constructivist method seems to better achieve this goal by guaranteeing longer lasting knowledge in a student's mind. In order to achieve this, the method was tested on two second level sections in the IT programme where the same topic of MS Access filters was presented. After identifying the lesson objectives, the term 'filter' was defined analogously with real life usage; the example used being that of a hot-drinks vending machine. As the discussion progressed, and being aware of how this machine functioned, the students immediately disregarded the point of following exactly the same procedure when trying to get a hot drink from a vending machine when certain specifications were needed regarding milk, sugar, etc. It was only when this observation was reached that the distinction to our students between what is called 'a filter by selection' (i.e., one when you try to separate one object from a whole similar set) as opposed to 'a filter by form' (i.e., one where the presence of certain specifications and restrictions is obligatory on the required object) was made.

A handout containing some information about students was given out in class. Things were introduced to the students who were working in groups as follows:

Teacher: *What type of filter would you use to find out how many students from the list have the name 'Maryam'?*

Students: *Filter by selection, teacher.*

Teacher: *That's right, but how would you find the answer if your teacher wasn't around to help you out?*

Students: *We could manually count all those with the name 'Maryam'.*

Teacher: *Okay, but wait…*

Another handout with 70 000 records was then distributed followed by the asking of the same question about the name 'Maryam'. A two-minute pause was allowed in order to find a solution.

Students: *Are we allowed to use Access help?*

Teacher: *Yes, of course.*

A couple of minutes passed before it was realised that eight students had already accomplished the task and found the answer, which was later explained on the board to the rest of the class by a volunteer. Though it took more time than it did with the first section, things progressed smoothly.

Teacher: *Now, how can we find the number of students with the name 'Mariam'?*

Here, almost the majority of the class knew the answer.

Teacher: *Okay, what if we needed to find out all of those under the name 'Maryam' or 'Mriam'?*

Students: *Two filters by selections would serve the purpose, after which we add up both results.*

Teacher: *Would the same be applied to find out those with the names 'Mryam' and 'Mriam' from Abu Dhabi Emirate in particular?*

Students: *Since more restrictions on the needed records are present, a filter by form would be appropriate.*

Teacher: *Absolutely correct.*

Afterwards, another handout with all the needed operations and wild cards was distributed in class (see Appendix E) but not discussed. It took most of the class only five minutes to find the solution. The same worksheet given to section 1 was used in section 2; this resulted in having almost the same number of students being able to solve all the problems (i.e. fourteen). Then, the lesson was summed up by one of the students to the rest of the class.

The following day, section 2 students were given the second worksheet discussed in section 1. Surprisingly, the majority of the class recalled the material discussed from the previous lesson. Thus the knowledge gained through the students' initiative explorations with the material, with provision for guidance from the teacher, seems to be more effective in the teaching and learning process.

Evaluation of learning methods

The two classes were of similar ability: their mid-term averages were exactly the same and their class work evaluations were also almost the same. A difference in the level of the homework and a quiz was noticed after trying the two teaching methods (see appendices C and D for the homework and quiz used).

Table 1 shows the marks of the homework (homework number 4 in the course), quiz 3 and the mid-term of the two sections (traditional: section 1 and constructivist: section 2). A blank cell means that a student was absent for that day (even though a zero mark is assumed, but we did not include that cell in our analysis).

The mid-term examination was given about a month before our experiment while similar results were recorded for all other homework assignments and quizzes. In other words, the level of the students was almost identical in all components of the assessment before our experiment was conducted.

Traditional			**Constructivist**		
Homework 4 (out of 10)	Quiz 3 (out of 15)	Mid-term (out of 30)	Homework 4 (out of 10)	Quiz 3 (out of 15)	Mid-term (out of 30)
8	9.75	26	7	10.5	28
8	5.25	25	7	10.5	29
6	9.75	24	8	9	26
6	9.75	25	8	12	21
6	10.75	28	8	9	26
6	7.50	26	7	9	24
6	15	26	8	10.5	18
		24	8	12	23
6	10.50	23	9	10.75	24
8	10.50	24	10	10.75	19
6	10.75	26	10	6	29
6	6.75	24	8	10.75	23
8	10.5	29	9	12.75	26
6	4.5	26	10	10.75	24
7	8.25	20	8	12	23
8	7.5	20	8	12	29
6	4.5	21	8	15	28
	13.5	28	7	10.5	28
7	15	24	10	15	23
Averages					
6	9	25	8	11	25

Table 1: Raw scores of Homework 4, Quiz 3, and the Mid-term.

Analysis of results

We used the step-by-step traditional method in section 1 and the constructivist method in section 2. On reflection, the following observations could be made.

1. The students from both sections scored similar results in the mid-term examinations (this shown as the line chart in Figure 1).

2. Section 2 students who experienced a constructivist style of teaching achieved a higher level in homework 4 and quiz 3 by 20% and 13% respectively compared to section 1 students. A clear distinction of this is seen in Figures 2 and 3.

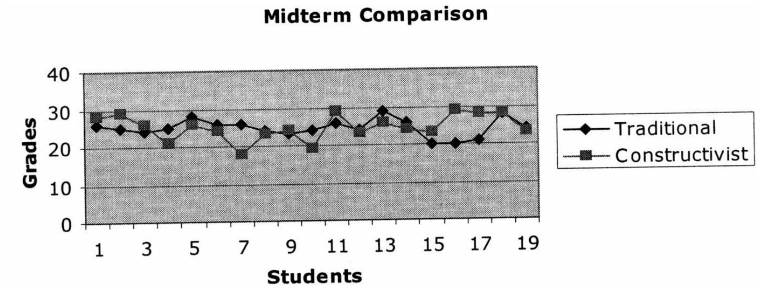


Figure 1: Mid-term examination marks.

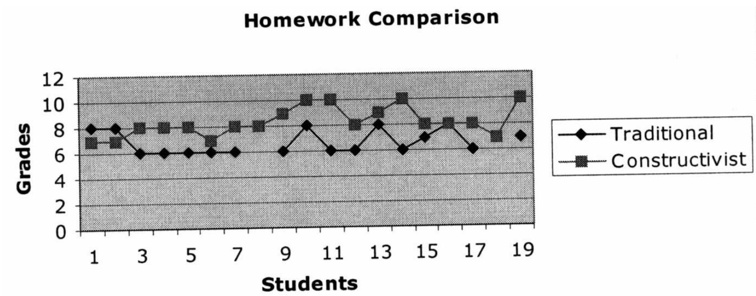


Figure 2: Homework 4 marks.

Conclusion

In contrast to the traditional step-by-step lecture-based teaching method, the constructivist teaching style has proven to be more effective to our students in the teaching and learning process. We found the constructive approach reflected positively on our students' learning as they were provoked towards finding solutions instead of being passively spoon fed. By continuously stimulating the student to share in the teaching process, learning is no longer an obstacle since at the end what is gained depends ultimately on the means followed. The benefits we found particularly encouraging from adopting a constructivist approach to teaching and learning included:

1. Knowledge is obtained through attempting to find it and becomes easier to recall later on.
2. Critical thinking is promoted and seems to result from improved learning confidence within the student.
3. Self-esteem increases along with self-assurance and motivates students to face

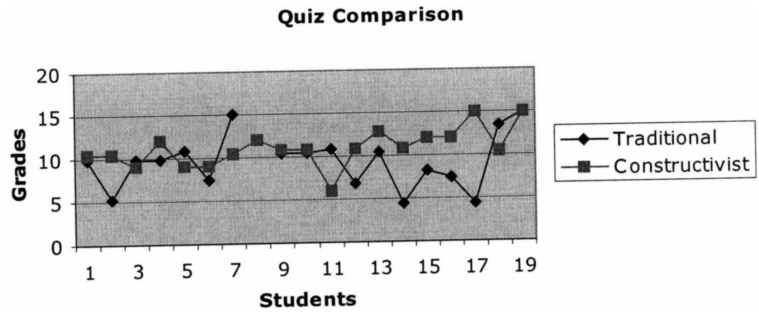


Figure 3: Quiz 3 marks.

new challenges.

4. Enthusiasm towards the learning process and creativity can be triggered when adopting this path to obtain knowledge.

The experiment on teaching Access filters to level 2 students in the IT programme at UGRU proved to be successful. However, the new teaching strategy needs to be carefully considered if attempting to apply it more widely since much more is involved in order to reach the desired outcome in contrast to the traditional step-by-step technique.

The outcomes achieved from our experiment have prompted us both to implement a constructivist method to teaching on a wider range of classes in other courses. This shall hopefully provide a clearer perspective on the issue from which broader generalisations about its impact on student learning will stem.

Acknowledgements

We are indebted to Mr Hussein Ahmed without whose support this project would not have materialised. His endless encouragement has always steered our experimentation towards innovative teaching practices. We would also like to thank Dr Brian Bielenberg for his initiative to start various professional development activities within our unit. Appreciation also goes to Ms Badia Karzoun for her thoughtful comments on an earlier draft of this paper. Through her efforts she has made the paper easier to follow and consistent. Finally to Mr Yousuf Suluh who put the final touches on the overall presentation of the paper and suggested many useful corrections.

Appendices

Appendix A

IT2 Access: Practice Worksheet on Filters

- Copy the file Univ.mdb from the X: drive to the W: Drive and open it
- Apply Filter by Selection or by Form on the table Courses to answer the following:
  1. What is the total number of records in the table? ....
  2. How many courses have a Capacity of 72? ....
  3. How many courses have Department ID BIO? ....
  4. How many courses Cost more than AED135? ....
  5. How many course Names begin with the letter ‘a’? ....
  6. How many course Names third letter is ‘o’? ....
  7. How many courses their CourseID ends with the digits 120? ....
  8. How many courses have a Cost equal to AED180 and their name starts with the letter ‘e’? ....
  9. How many courses Cost between AED150 to AED200? ....
  10. How many courses their Capacity is not between 100 and 150? ....
- Compact and repair the database.
- Exit MS Access
- Hand-in your work.

Appendix B

IT2 Access: Worksheet on Filters

- Copy the file Student Data.mdb from the X: drive to the W: Drive and open it
- Apply the proper Filter type on the table Students Info to answer the following:
  1. What is the total number of records in the table? ....
  2. How many students have the first name Salim? ....
  3. How many students have the first name Salem? ....
  4. How many unmarried students are there? ....
  5. How many IT students are there? ....

6. How many students have an Age between 17 and 20? ....
7. How many students are from Dubai and aged above 20? ....
8. How many students have the last name Ali and who are IT majors? ......
9. How many married students are from Abu Dhabi? ....
10. How many non-IT students have a first name starting with the letter ‘S’ and their last name has exactly 5 letters? ....

- Compact and repair the database.
- Exit MS Access
- Hand-in your work.

Appendix C

IT2 Access: Homework on Filters

- Copy the file Univ.mdb from the X: drive to the W: Drive and open it
- Apply Filter by Selection or by Form on the table Courses to answer the following:
  1. How many courses have a Capacity of 110? ....
  2. How many courses have Department ID CSCI? ....
  3. How many courses Cost less than AED135? ....
  4. How many courses Cost AED180 or AED225? ....
  5. How many course Names start with the letter ‘p’? ....
  6. How many course Names third letter is ‘s’? ....Sort records by Capacity in descending order, what is the first Capacity? ....
  7. How many courses have a Capacity that is not between 94 and 112? ......
  8. How many courses have a Course ID whosae second letter is ‘s’ or their Units is 3? ....
  9. How many courses Cost AED135 or AED270? ....
  10. How many courses have a Department ID which is exactly 6 letters, their Cost is not AED150, are not 4 Units, their Capacity is less than 150, and their Name ends with the letter ‘y’? ....
- Compact and repair the database.
- Exit MS Access
- Hand-in your work.

Appendix D

IT2 – Quiz on Filters

- Copy the file Family.mdb from the X: drive to the W: Drive and open it.
- Apply Filter by Selection or by Form on the table Children to answer the following:
  1. What is the total number of records in the table? ....
  2. How many children have child IDs contain the digit 5? ....
  3. How many female children have a name that starts with the letter 'S'? ....
  4. How many male children were born on or after October 13th ,1981? ......
  5. How many female children having their mother's name start with the letter 'A'? ....
  6. How many children have a family ID in the range 2000 to 4000? ....
  7. How many children with names 'Nuha' or 'Afra' have the same name as their mother's? ....
  8. How many children have names consisting of exactly five characters and they were born in the 1980's, and their mother's name start with a letter between 'A' and 'K'? ....
  9. Sort records by the two columns: family ID in ascending order and by child ID in descending order. What is the name of the child with record number 33? ....
  10. What is the fastest way to directly 'navigate to a record' in Access while you are in the datasheet view? ....
- Compact and repair the database.
- Exit MS Access
- Hand-in your work.

Appendix E

Access Filter and Query Expressions
Relational Operators

Operator	Example	Meaning
>	(a>5)	a greater than 5
<	(a<5)	a less than 5
=	A=5	A equal to 5
>=	(Name>=‘M’)	Name starting with M or after M
<=	(Name<=‘K’)	Name starting with K or before K
<>	Name<>‘Ali’	Name is different from Ali
Between	Birth date **Between** #1/1/82#	Born in 1982 or 1983 **And** #1/1/84#
Between	Name between ‘A’ and ‘D’	Name starting between A and D
Between	A between 5 and 10	A between 5 and 10

Wild Cards

Operator	Example	Meaning
Like *	Like ‘h*’	All names start with letter h
Like ?	Like ‘???*’	All names having exactly 3 letters
Like []	Like ‘[A–K]’	Name starts with A through K

Note that the word ‘like’ should not be written.

Logical Operator

Operator	Example	Meaning
AND	(a>=5) and (a<=10)	‘a’ between 5 and 10
OR	(a<5) or (a>10)	‘a’ not between 5 and 10
NOT	Not(name=‘Ali’)	Name not equal ‘Ali’

References

BROOKS, J. G. AND BROOKS, M. G. (1993). *The case for constructivist classrooms*. ASCD: Alexandria, VA.

JAWORSKI, B. (1998). *Constructivism and teaching: The socio-cultural context* [online].
Available from: `http://www.grout.demon.co.uk/Barbara/`

MATTHEWS, M. R. (1998). *Constructivism in science and mathematics education* [online].
Available from: `http://wwwcsi.unian.it/educa/inglese/matthews`

Information technology in engineering education

Fahar G. Hayati and Anas N. Ali

Ajman University of Science and Technology, Ajman, United Arab Emirates

This paper investigates the application and impact of information technology on engineering education, and examines the extent to which it should be used. In particular, the integration of multimedia in theoretical and laboratory lectures, with emphasis on mathematics and applied science courses, is examined and the required hardware and software infrastructure to realise such integration is outlined. In addition, a case study is presented where the theoretical lectures for a particular engineering course in Ajman University was implemented using one aspect of information technology, namely, multimedia. The study examines the impact of multimedia on the teaching and learning process. Statistical results based on a survey conducted on a sample of students are also presented.

Introduction

The last two decades have witnessed very dramatic changes in the way information technology (IT) is used in education. From a 'teacher-centred approach', the emphasis has now shifted to one that gives priority to learning (Indmen, 2004). As a consequence, today a 'learner-centred approach' has been encouraged that requires teachers to be more involved and be the ones who motivate the learner, rather than being solely responsible for the transfer of knowledge.

The teaching of subjects such as mathematics and electronics at tertiary level has been characterised by increasing difficulty in attracting new students, by problems in the learning process, by a lack of motivation, and by those who enrol only to drop out (Pais, 2004). We believe that the integration of IT in engineering education will alleviate some of these problems. IT can be used to enhance the teaching and learning processes while at the same time providing a flexible means of education and reducing overall costs.

The diversity of components in engineering education requires careful assessment of the impact of IT on the outcome of these components and the overall impact on the

programme outcome. The goals of engineering education should be directed towards graduating an engineer who, in addition to standard engineering skills, is capable of pursuing independent life-long learning and can interact actively in an environment where a strong theoretical knowledge base is required. However, many challenges still currently face engineering education. They include:

- providing diversely balanced educational programmes which still achieve predetermined goals;
- provision of the right educational tools and resources;
- overcoming faculty resistance to change;
- changing students' attitudes towards learning.

The question we pose is what, 'Can IT provide to meet these challenges'?

IT implementation and infrastructure

In general, IT can be integrated in diverse applications regarding engineering education. It can be used in:

- programme management, which could include course delivery, electronic archiving, student follow-up, and online services;
- enhancing information resources, such as digital libraries, online courses, archived lectures and tutorials, etc;
- supporting teaching, aided with knowledge delivery (smart classroom) and online courses;
- assessment and quality assurance.

The infrastructure needed for proper IT implementation in engineering education includes:

- wideband network with supporting software and hardware;
- multimedia facilities for production and delivery;
- learning arena in the form of smart classrooms, smart laboratories, etc.;
- adequate supply of IT-based computer-aided resources.

Multimedia in theoretical laboratory courses

It is seen that text, simulations, animations, video, images, and sound can facilitate better visualisation and comprehension of theory (Zywno, Brimley and White, 2000). Having said that, an appropriate IT tool used in implementing theoretical and laboratory courses is multimedia. Some engineering courses, namely, mathematics and applied science based courses, are well presented and explained through the use of multimedia.

Multimedia-based courses require classrooms with network-enabled laptop computers with access to the Intranet and the Internet. Lectures are presented electronically with multimedia-enriched slides. Websites can also be used to disseminate lecture material, assignments, and updates, which will enable students to access information synchronously (anywhere, anytime) outside the normal lecture room (Zywno, Brimley and White, 2000). The CD-ROMs accompanied with course textbooks can also be used as a supplement in the teaching and learning process.

Benefits of multimedia-based courses include:

- improved quality of teaching and learning, where information is presented in a variety of ways: this introduces flexibility for both teachers and learners;
- course content is adaptable and thus easy to update;
- stimulating interactive learning environments for students and teachers alike;
- the facilitation of collaborative learning and teamwork.

The degree of multimedia integration in laboratories may differ from basic laboratories to advanced ones. We believe that more multimedia should be incorporated in first and second year laboratory courses, where basic science topics are involved. The hardware and software infrastructure needed for multimedia-based laboratories include:

- computers with multimedia peripherals (19-inch displays, DVD players, webcams, etc.), with broadband access to the Intranet and the Internet;
- multimedia-based materials for virtual experiments (DVDs, video files, Java applets, Macromedia Flash clips, etc.);
- simulation software packages (Matlab, Multisim, LabView, etc.).

In addition to conducting the physical part of an experiment, a session in a multimedia-based laboratory can include simulation of experiments via suitable software packages and also, experiment demonstrations via video clips, Macromedia Flash clips, and web-based Java applets can be included.

The advantages of multimedia-based laboratories include:

- experiment verification via simulation and video demonstrations;
- the feasibility of implementing difficult experiments that require expensive hardware;
- service to online universities and the creation of an environment where students can access the laboratory ‘anytime, anywhere’;
- institutions being able to rely on the expertise of other consortium members to create laboratories in fields in which they may not have current expertise;
- laboratories being made safer for the student by reducing university liability concerns about experiments involving lasers, toxic materials, etc.

Having mentioned the importance of multimedia-based laboratories, we consider such laboratories as a complement to a department’s laboratory curriculum, and not as a complete replacement of all ‘in-person’ laboratories.

For multimedia to be incorporated in courses and laboratories, it becomes imperative to have multimedia authoring facilities within the faculty. This can be realised by having an IT department whose functions include the authoring of multimedia materials for various courses, and to train teachers and students alike on how to use, produce, and deliver IT efficiently.

Case study

In this paper, a case study is presented where multimedia was used to implement the lecture component of Course 233201 Engineering Materials, which is offered to second year students at Ajman University. The study shows the impact of this implementation on the student’s learning ability. Course 233201 is a fundamental course that introduces different types of materials with their respective mechanical, electrical, magnetic, and optical properties. The main objective of the course is to enable students to select the best material for the appropriate engineering application. Hence, introductory courses, like this one, provide a good place to access the effective use of multimedia.

Multimedia usage in Course 233201 comes in the form of lecture implementation via PowerPoint presentations. Each presentation slide contains text, graphics, animation, and video clips, as depicted in Figure 1. In addition, the textbook CD-ROM is also used as a supplement to the teaching and learning process. A lecture session may also include viewing of DVD documentary films related to course topics to further broaden the students’ knowledge and understanding.

To determine the impact of multimedia integration in such a course, a survey was conducted on fifty students, and feedback was obtained via a questionnaire designed to measure the learning abilities of students through the use of multimedia. The results of the survey can be summarised as follows:

- 81% preferred multimedia-based lectures over conventional lectures;

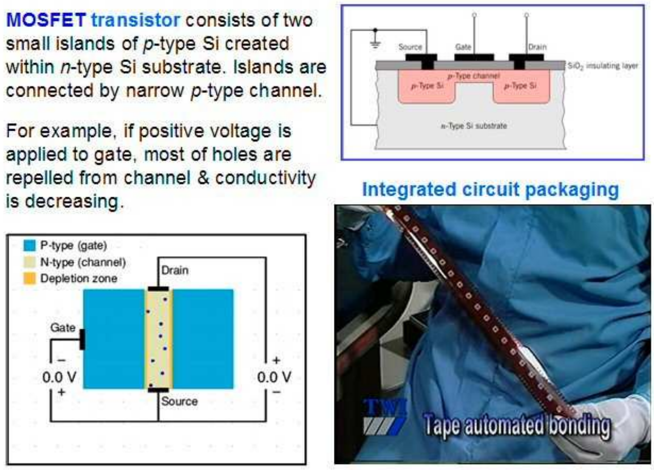


Figure 1: An example electronic slide showing multimedia content.

- 71% agreed that multimedia increased the student's learning abilities;
- 79% agreed that multimedia eases lecture follow-up;
- 73% found multimedia interesting and entertaining;
- 83% said that too much information was given per lecture.

Although the study was carried out on a limited sample, it is clear from the results that the effect of multimedia is significant. Unfortunately, a comparison was not made with students taking the course via conventional means.

Conclusions

The implementation and impact of IT in engineering education has been presented. This paper has emphasised the integration of IT in theoretical and laboratory courses. The paper has also presented a case study where IT was integrated into an engineering course at Ajman University. We conclude that:

- integration of IT in engineering education does enhance the overall teaching and learning process;
- teachers and students need to be trained on how to use, produce, and deliver IT efficiently;

- use of IT in all aspects of education continues to grow;
- the case study presented is still in its initial stages and further development is needed;
- the proper usage of IT still requires more research on how best to apply it.

References

INELMEN, E. (2004). E-mentoring: A novel approach in the use of technology in education. *Proceedings of the 5th International Conference on IT Based Higher Education and Training* (pp. 183–186), Istanbul.

PAIS, C. AND ET AL (2004). A strategy to improve engineering teaching process based on an e-learning approach. *Proceedings of the 5th International Conference on IT based higher education and training* (pp. 227–230), Istanbul.

ZYWNO, M. S., BRIMLEY, W. J. G.AND WHITE, W. E. (2000). Effective integration of multimedia courseware in engineering education at Ryerson Polytechnic University, *Proceedings of the 3rd UICEE Annual Conference on Engineering Education* (pp. 25–34).

Online webcast: Computer-mediated communications tools used with teachers and students in virtual communities of practice

Vance Stevens

Foundation Computing, The Petroleum Institute, Abu Dhabi, United Arab Emirates

Introduction

This presentation was a demonstration of webcasting utilising freely available software tools operating at normal connection speeds over low-end computers. Participants in the demonstration were members of a community of practice known as *Webheads in Action* (WiA), whose members have been sharing each other's expertise and ideas for using computer-mediated communications (CMC) tools in education in online environments ranging over the globe since the group's inception in late 2001–2002. Group members correspond continually and meet regularly online, and often collaborate with one another in each other's web-based projects, including helping each other to make presentations at international conferences and workshops where these tools are of interest to other educators. The community has around 400 members, a very small proportion of whom have ever met face-to-face. Nevertheless, WiA is an long-running, robust, and highly interactive community whose members have proven to be consistently supportive of one another and reliable in their collaborations.

Two Webheads agreed in advance to support me in this presentation. They were Michael Coghlan, a teacher-trainer in Adelaide,[1] who talked to us from a distance about the use of virtual classroom tools in e-learning environments, particularly with focus on the theme of an online conference he was preparing: Strategies for Effective Learning. The other presenter was Sergei Gridyushko from Minsk[2] who talked about Webheads participation in a recent BelNATE conference in Belarus as one example of the use of CMC tools in building communities that in turn pitch in to train other teachers in their use. Two other Webheads also dropped in during the demonstration: Susanne Nyrop speaking from Denmark, and Rita Zeinstejer who visited from Argentina.

[1]http://users.chariot.net.au/ michaelc/usingvclassrooms.htm
[2]http://www.ir.bsu.by/kel/homesergei.htm

Webcasting is all at the same time a device utilised in strengthening cohesion among members of the community, a topic of interest among participants, and a vehicle through which group members can demonstrate the fruits of their collaborations, as shown in demonstrations such as that given at the METSMaC Conference. Webheads often organise events involving webcasting. Sometimes the events are recorded and placed online. Two recordings of conference presentations made using one or more of the tools discussed here are:

- I engaged Webhead community members joining me from their respective locations at many junctures during my talk entitled 'The future is now: How CMC tools for professional development enhance learning environments for students', delivered at the CALL-IS Academic Session, March 31, 2005 at the TESOL Conference in San Antonio. The online handout for the talk is cited below[3] while the webcast recording is available at the address provided.[4]

- I gave a workshop entitled 'Blogging in online communities of practice: Impact on language learning and teacher professional development', again with participation of online participants from the Webhead community, but with me in Abu Dhabi and the workshop participants physically at the QTEN Conference in Qatar on April 30, 2005. The online handout is available at the address provided below[5] and the webcast recording is also available.[6]

As educators with limited budgets bent on exploring the use of CMC in education, WiA members volunteer their time to promote each other's, and in return, their own, professional development. Interactions among members of the group are decidedly constructivist in nature, which is to say that group members interact in a zone of proximal development where scaffolding constantly occurs, and where members contribute to each other's development while acting out of mutual self-interest. In order to level the playing field, no assumptions are made about a member's means, expertise, or background in technology. Fortunately there are numerous CMC tools available on the Internet which are freely available and intuitively easy to use. WiA members excel in helping each other optimise these free technologies for educational purposes. Community members often provide suggestions as well as tangible help to supplement the intuitions of members who need to know how to use a CMC tool and for what purpose. There is evidence to suggest that members who learn through such dynamics within the community tend to understand more fully how to apply constructivist methods in their own interactions with students, so that there is a payoff in education deriving from participation in communities of practice such as WiA.

Webheads have engaged in analysing themselves in the context of communities of practice. Etienne Wenger is perhaps the best-known proponent of the concept of

[3] http://www.homestead.com/prosites-vstevens/files/efi/papers/tesol/2005/gvs_pres.htm

[4] http://home.learningtimes.net/learningtimes?go=774660 (beginning at counter 4:27:45 on the recording)

[5] http://prosites-vstevens.homestead.com/files/efi/papers/qten2005/vancestevens2005qten.htm

[6] http://home.learningtimes.net/learningtimes?go=805285

communities of practice. In one schematic diagram he defines communities of practice (CoP) as simply '... groups of people who share a passion for something that they know how to do and who interact regularly to learn how to do it better' (Wenger, 2004a). Wenger distinguishes CoPs from other communities (a neighbourhood for example) as sharing three crucial elements: (1) a common domain of interest (like a speciality, not necessarily recognised as a domain of expertise outside the CoP), (2) a cohesion and interaction within the community (as opposed to simply shared membership in an organisation), and (3) a practice or expertise (as opposed to a common passive interest, in books or movies for example) (Wenger, 2004b). Snyder (n.d.) elaborates further on CoPs, 'What holds them together is a common sense of purpose and a real need to know what each other knows'. Snyder's page is a portal for one of many CoPs which have come together out of an interest in CoPs themselves, and these are often excellent sources of material on the topic. Within Webheads there are members who have joined in order to experience participation in a vibrant CoP while studying the topic in the course of doctoral studies; e.g. Johnson (2001; 2003).

Wenger, McDermott, and Snyder (2002) use the term 'distributed' CoPs to refer to groups whose members meet online. It so happens that the tools such groups use to affect these meetings are the very ones that teachers are interested in to promote communication among students and peers, who may or may not be distant from one another, but who find their work is facilitated by meeting over the Internet in real time.

Many Webheads participants have incorporated techniques for community building creatively in their particular blended learning situations. One is Dafne González, who used her experience with Webheads to create her own online video-enhanced English course for architecture students in Spain (González, 2003). A second teacher is Buthaina Alothman from Kuwait University, who compares her work before her encounters with Webheads to her more recent work, as influenced by the community of practice (Alothman, 2003). Among Buthaina's accomplishments was to have her students make their end-of-term presentations online through a voice chat portal, and to invite community members to listen to and help evaluate the presentations (Alothman, 2004). A third Webhead to apply CMC techniques to her face-to-face classes is Aiden Yeh in Taiwan. Aiden has created web pages documenting her students' work with community members, for example a meeting with Webheads songwriter Michael Coghlan, where her students listened to his songs online, then met the composer to discuss his lyrics (Yeh, n.d.). These projects are more fully detailed in Stevens (2004b, 2004c).

Webheads in Action

Webheads meet regularly online to explore ways of using the latest free communications technologies that work over the Internet for language learning and teacher training. These technologies include asynchronous tools such as blogging and synchronous ones such as text, voice, and webcam-enabled chat services (see Stevens, 2004a). Webheads have consistently introduced novice computer user teachers and students to CMC environments that are educational in nature, documented their experiences with these

tools, and used them to work collaboratively on numerous student projects (Stevens, 2004b).

Webcasting is an important aspect of the domain of knowledge addressed by WiA. In a group that comes together to learn more about CMC, communications are both an object of study and the medium of dissemination of that knowledge. In fulfilling both these goals, group members with experience in earlier communities have moved from text chat in the 1990s to avatar-enhanced three-dimensional virtual environments at the turn of the century (still text only), and on to voice-enhanced synchronous communications from 2000 onwards. We have emerged into an era where, while we still extensively use text chat, voice and video have become more and more trouble-free, where operating systems allow truly plug and play installment of hardware, bandwidth versus compression have combined to accommodate improved Internet delivery, and the software for interfacing the user with the person at the other end can be quickly downloaded and installed and easily understood by all parties in the communications matrix.

The remainder of this paper describes how a webcast is set up and details the free software tools used in the broadcast from the METSMaC Conference held in Abu Dhabi on April 27, 2005.

Webcast components

As the demonstration was meant to show, webcasting for free over the Internet is not technologically challenging. Components for a successful webcast include:

- interactants with a reason to meet;
- an agreed date and time to meet – it is important to provide clear instructions on how participants can access the webcast venue. Time of the event should be given in GMT. Reliable time conversions worldwide can be found at the address below;[7]
- an Internet connection available on the correct date and time – using the tools mentioned here, it does not have to be broadband; the participant at the METSMaC webcast from Minsk was using a 33.6 kbps dial-up modem;
- a shared set of CMC software running on each computer and configured for any firewalls that might be present. This is described in more detail below.

It is important with regard to the latter to test the software at the location (meaning in the room and at the computers being used for the webcast) well before the date of the actual presentation. On computers used for the METSMaC Conference we specified:

- administrator privileges on our computer in order to do installations on the fly;

[7] http://www.timeanddate.com/worldclock/fixedtime.html

- ability to use *Elluminate* voice presentation software at Learning Times[8] and the *Alado* presentation portal at the address provided below;[9]
- ability to use *Yahoo Messenger* with voice and webcam capability (you need a microphone at minimum and a webcam installed, if you have one);
- ability to use *Tapped In* text chat. This is available at the address below;[10]
- ability to project the monitor and broadcast voices to the room via speakers attached to the computer.

The set of software ready for the webcast should include, in addition to the primary presentation webcast client software:

- a stable text chat in which to meet in case of problems with the preferred location, or in case any participants have trouble reaching that location. In either event participants can fall back to the meeting point and decide how to proceed with the webcast. Often such meetings take place among individuals without others in the webcast being aware that there is any problem (or the individuals might not have a problem, but are just taking advantage of the back-channel away from the prime chat area);
- an alternative to the preferred location. In case the preferred chat site is having server problems or is inaccessible by individuals needed in the chat, it is good to have an alternate plan thought out in advance.

The ideal presentation webcast client software itself might have most of the following features (or alternatively, a combination of tools might be used in order to have available as many of these features as possible):

Access

- by anyone; no prior registration or password required;
- smallest (fastest) possible download;
- by both Macintosh and PC; friendly to a range of browsers;
- allow detection of buddies online, so participants can see when the others are logged on to the Internet.

A robust text chat that allows

- copying on the fly from the chat log and pasting elsewhere;

[8]http://www.tinyurl.com/y3eh (may require update of plug-in and installation of Sun Java)

[9]http://www.alado.net/webheads (log on with any name and no password). Installation of iVocalize may be required.

[10]http://www.tappedin.org (also requires Sun Java).

- clicking on URLs given in the chat and having these open in a browser;
- a means of ‘emoting’;
- viewing ‘profiles’ of others in the chat (by clicking on their names);
- scrolling the logs easily;
- saving a record of the chat log;
- viewing what others are writing as they type (none of the chats we use do this though ICQ used to).

A clear and lucid voice chat

- duplex (though this can cause feedback if headphones not used);
- if simplex, then a means of letting participants queue for the microphone in hands free mode;
- a way for the moderator to regain the microphone in case of inattention or misuse.

Video webcam

- cams of numerous participants viewable at once;
- a variety of broadcast quality settings depending on bandwidth.

An interactive whiteboard that allows

- text;
- pasting of pictures from the OS environment;
- grouping/ungrouping, resizing, moving images;
- paint and graphics tools;
- load-in of PowerPoint and other prepared slide objects and a means of easily changing screens during presentations;
- an option for the moderator to browse screens alone or synchronise viewing with chat participants.

Browsing

- a means of displaying URLs to everyone in the chat, usually by opening new browser windows on participants’ computers;

- participants can then browse at will until the moderator forces change to a synchronised window.

Application sharing

- allows applications on the host computer to run on other computers in the session.

Screen sharing

- allows the moderator to share the entire screen or just one window on the desktop archives;
- recordings can be made that replicate the entire session exactly;
- logs of the session e-mailed automatically to participants.

Details of webcast software used at METSMaC

There are many free tools available that include a number of these specifications. It is not in the scope of this paper to review the pros and cons of all software that fits these criteria. Rather, I will focus on the software used during the METSMaC Conference where the demonstration took place.

Yahoo Messenger

Yahoo Messenger is an instant messenger (IM) tool that allows detection of buddies online, so participants can see when the others are logged on to the Internet. Other IMs can be used as well, and in fact participants often will monitor several at once. However, we prefer *Yahoo Messenger* because it has other features that particularly suit it to voice and webcam conferencing.

Webcasts can be done with *Yahoo Messenger*. I have broadcast presentations and seminars from conferences using only this tool. *Yahoo Messenger* allows multiple webcams to be shown while participants interact in voice-enabled conference where the number of participants is limited only by bandwidth. *Yahoo Messenger* is unique among free webcast tools in that it allows multiple interactants in both webcam and voice mode, whereas the other free instant messenger services tend to limit participants, usually to one-on-one. However, *Yahoo Messenger* is not well adapted for serious professional broadcasts. Voice quality varies, especially in conjunction with video, and the program can crash or behave erratically. Furthermore its constant demands for attention to chat windows and micro-management of webcam and conference areas can be distracting to presenters already multitasking their presentations.

Here is how *Yahoo Messenger* compares to the ideal webcast client:

Access

- requires prior registration with Yahoo system;

- small download, easily installed;
- fully featured for PC but less friendly to Mac.

A robust text chat that allows

- copying from the chat log and pasting elsewhere;
- very graphic means of 'emoting';
- viewing 'profiles' of others (but profiles are rarely filled out);
- scrolling the logs easily;
- saving a record of the chat.

Voice chat

- medium quality;
- duplex (though this can cause feedback if loud speakers are used);
- hands free mode.

Video webcam

- numerous cams are viewable at once;
- quality settings control; super mode and image size.

Tapped In

When running a webcast you need a help desk that everyone can reach. I like to use http://www.tappedin.org as a reliable anchor for online events. *Tapped In* is a free and interactive portal for a community of educators that allows both member and guest access to the Java-based text chat. Participants in our webcasts are told that if help is needed, they can go to the text chat there (log in as a guest if not a member of *Tapped In*) and someone will be on hand to assist.

Access

- by anyone; registration advantageous but guest access allowed;
- acceptably fast download;
- by both Macintosh and PC.

A robust text chat that allows

- copying from the chat that entails sending chat contents to a 'pasteboard' and pasting from there;
- clicking on URLs given in the chat that opens them in a browser;
- a means of 'emoting' in text;
- viewing 'profiles' of others in the chat (by clicking on their names. As most users are registered educators, there is often useful information of a professional nature);
- scrolling the logs easily;
- a record of the chat to be e-mailed to registered participants.

Whiteboard allows

- text messages only.

Browsing

- is only available if participants click on URLs in chat.

Archives

- logs of session are e-mailed automatically to registered participants.

Presentation webcast client software

Webheads are fortunate to have gained the informal support of two providers of voice interactive presentation technologies: *Learning Times* and *Alado*. This support has accrued from instances of chance collaboration followed by periods of working collaborative arrangements, followed again by grants of chat rooms dedicated to supporting Webheads education-oriented webcasting sessions. Whereas certain Webhead members are granted moderator privileges, anyone is free to access the chat rooms.

Alado

The *Alado* room is at http://www.alado.net/webheads. Its software is from *Talking Communities* and its plug-in is called *iVocalize*. To enter this room you select 'Login information' at the site URL and then key any name (no password) into the chat area you wish to enter. The *Talking Communities* client provides text and voice chat with the presentation screen controlled via moderator-driven Internet browsing, so that presentation materials have to be up on the Internet somewhere. There is no means of showing a webcam, or interacting on the whiteboard, or sharing the moderator's screen, windows, or applications. However, the *iVocalize* plug-in provides consistently clear sound along with:

Access

- by anyone; no prior registration or password is required;
- acceptably small download;
- by PC; working on Macintosh but there are still problems.

A small text chat window that allows

- copying from the chat log and pasting elsewhere;
- clicking on URLs given in the chat and having these open in a browser;
- no means of ‘emoting’;
- scrolling the logs easily;
- saving a record of the chat in the recording.

A clear and lucid voice chat

- simplex;
- hands free mode;
- means of letting participants queue for microphone;
- way for the moderator to regain the microphone in the case of misuse.

Browsing

- the moderator can display URLs to everyone in the session via the presentation window.

Archives

- recordings can be made that replicate the entire session exactly.

Learning Times
Learning Times (LT) provides *Elluminate Live* to its registered users. The normal entry to the *Elluminate* chat room via LT is from the login screen (select ‘Meeting Room’ in the left-hand frame). This room is available to anyone on a casual basis. Many LT members also have rooms which registered visitors to LT can click on and access, or visitors can go directly to the desired room (after log on) if the URL is available. As an example, the Webheads *Elluminate* room is available at the address provided.[11]

[11] http://home.learningtimes.net/learningtimes?go=273662

Potential attendees are always asked to register in advance and enter the room well ahead of the presentation in order to download and install the required software.

Of the software used in this demonstration, *Elluminate* has the most comprehensive of the set of webcast and online presentation tools:

Access

- prior registration with LT and password required;
- fairly hefty download;
- by both Macintosh and PC, both working well.

A barely sufficient text chat that allows

- copying from the chat log and pasting elsewhere;
- a good means of 'emoting';
- scrolling the logs, but not all that easily;
- saving a record of the chat only in the final recording.

A clear and lucid voice chat

- simplex;
- hands free mode;
- a means of letting participants queue for the microphone;
- a way for the moderator to regain the microphone in the case of misuse.

Video webcam

- only one cam is viewable at a time;
- has a variety of quality settings to accommodate the bandwidth.

The highly interactive Whiteboard accommodates

- text, paint, and graphics tools;
- pasting of images and objects from the OS environment;
- grouping/ungrouping, resizing, moving images;
- the load-in of PowerPoint and other prepared slide objects and a means of easily changing screens during presentations;

- an option for the moderator to browse screens alone or synchronise browsing with the chat participants.

Browsing

- means of displaying URLs to everyone in the chat, usually by opening new browser windows on participants' computers;

- participants can then browse at will until the moderator forces change to a synchronised window.

Application sharing

- allows applications on the host computer to run on other computers in session screen sharing;

- can share the entire screen or certain windows archives.

Archives

- recordings can be made that replicate the entire session exactly.

Running the webcast

Assuming the ingredients are all in place and working, then participants convene online, usually in advance of the appointed time. When I log onto the Internet prior to webcasting, I launch *Yahoo Messenger* and it tells me at a glance if other people I expect to meet are already online. If so, I will greet them in *Yahoo Messenger* and find out if they are in touch with other participants. As others appear online, they may do the same.

I will then go to *Tapped In* and set its chat window down the left-hand side of my screen. Then I can tell if anyone speaks in the chat and enlarge the window if anyone does. I might keep an eye on this as we are setting up, but once the session begins I find it hard to monitor this chat, so I usually designate someone in our group to remain engaged there and alert me if there is anything said there that requires my attention.

I then launch the presentation client we will use for the day and after seeing that it works, start doing sound checks with others who have also come early, get their webcams on my screen via *Yahoo* perhaps, and upload slides for the presentation if possible. As this happens just prior to webcasts, depending on how formal the occasion, there might be a discussion in process online when the session is due to begin, possibly involving participants helping each other set sound levels and make sure microphones and webcams are working, helping each other troubleshoot, or just comparing vagaries of the weather. This sometimes continues in the presence of the audience, who often have the feeling of walking in on the middle of something rather than something about

to begin. At a previous engagement I was five minutes into a demonstration when someone from the audience spoke up and asked, ‘What is going on here?’

Since most of the work in webcasting is essentially done in preparation, the webcast itself generally runs smoothly. With experience, one learns to position the webcam in the vicinity of the monitor so that eyes are looking into the camera when speaking, and it is good technique to pan the audience or solicit other speakers’ videos when not. Lighting is important: try facing windows rather than having brightness at your back. I try to make my webcast presentations as interactive as possible. I switch off my microphone frequently to avoid the situation of speaking when no one hears, and at those times I solicit feedback in the form of smileys or questions online. I try to get people using the whiteboard. If there is a poll feature, I try to use that.

For the METSMaC Conference, we had planned to spend the first half of the programme in *Elluminate* and the second half in the Alado portal, but one of the online participants was not able to reach *Alado*, so we ended up staying in LT the whole time. However, we did visit the *Alado* portal, but in a novel way.

One of the interesting features of *Elluminate* is the ability to select a window on your desktop and send that out to all participants online. This is a remarkable feature, allowing participants not to only browse to the same URLs the moderator is visiting, but to see the moderator scroll on the page, or work in any application window selected, for that matter.

In this case I shared a browser window with all participants in *Elluminate* and in that window I logged on to *Alado*. Once into the *Talking Communities* chat the participants in the *Elluminate* portal could see me conversing in text chat with someone there. On my own computer, I could speak to that person, and then go back to the *Elluminate* client and speak to the participants there. The online participants could not hear each other’s chat sessions, but the on-site audience could see and hear everything.

Connectivity was not good over the ISDN line at the conference venue. Timeouts occurred frequently when I was sending video or trying to talk, and at other times of high demand on bandwidth. Nevertheless, we were able to get the gist of the online presentations and take questions from the audience and handle them online. One of the questions was to ask how science teachers might use these tools, and off the top of my head, I suggested an online science fair.

If the connection had remained stable, it would have been a better presentation. We are perhaps pushing the limits of what we can get for free, but it is always encouraging to experience how the Webheads community pulls together to assist with professional development.

Conclusion

This paper has shown how webcasting can be implemented over the Internet using freely downloadable tools, especially with the help of a vibrant online community. It is argued that teachers who utilise social constructivist methods in their own professional

development are in turn better able to use them with students. For this reason involvement in webcasting for interaction with peers can lead eventually to positive outcomes in the classroom.

Appendix

All CMC tools and web portals used and/or referred to in this paper can be found at the following addresses:

Alado voice portal (for Webheads): http://www.alado.net/webheads

Elluminate: http://www.elluminate.com

Learning Times: http://www.learningtimes.net

Talking Communities: http://talkingcommunities.com

Tapped In: http://www.tappedin.org

Webheads in Action: http://www.webheads.info

Yahoo! Messenger: http://messenger.yahoo.com

References

ALOTHMAN, B. (2003). *How participation in a CoP informs and influences personal teaching* [online].
Available from: http://www.geocities.com/esl_efl_ku/.

ALOTHMAN, B. (2004). *First live webcast of project by students (2003–2004)* [online].
Available from: http://alothman-b.tripod.com/wia_162finalproj.htm.

GONZÁLEZ, D. (2003). Teaching and learning through chat: A taxonomy of educational chat for EFL/ESL, *Teaching English with Technology*, **3**(4), October 2003 [online].
Available from: http://www.iatefl.org.pl/call/j_review15.htm

JOHNSON, C. M. (2001). A survey of current research on online communities of practice, *Internet and Higher Education*, **4**,1–16.

JOHNSON, C. (2003). *Portal page for: Dissertation: Establishing an Online Community of Practice for Instructors of English as a Foreign Language* [online].
Available from: http://www.scis.nova.edu/ johnschr/

RYDER, M. (2005). *Constructivism* [online].
Available from: http://carbon.cudenver.edu/ mryder/itc_data/constructivism.html

SNYDER, E. (n.d.) *TCM.com Inc. page on CoPs (Communities of Practice)* [online]. Available from: http://www.tcm.com/trdev/cops.htm.

STEVENS, V. (2004a). The skill of communication: Technology brought to bear on the art of language learning, *TESL-EJ*, **7**(4) [online].
Available from: http://cwp60.berkeley.edu:16080/TESL- EJ/ej28/int.html.

STEVENS, V. (2004b). *Voices heard having F.U.N. in online communities of practice: A presentation by Vance Stevens*. Presented at the Annual TESOL Convention, Long Beach, 3 April 2005 [online].
Available from: http://www.homestead.com/prosites-vstevens/files/efi/papers/tesol/colloquium2004/fun00.htm.

STEVENS, V. (2005). *WFW: Writing for Webheads you can chat with us live, online, free* [online].
Available from: http://www.homestead.com/prosites-vstevens/files/efi/software.htm.

WENGER, E. (1998). *Communities of practice Learning as a social system* [online].
Available from: http://www.co-i-l.com/coil/knowledge-garden/cop/lss.shtml

WENGER, E., MCDERMOTT, R. AND SNYDER, W. M. (2002). *Cultivating communities of practice: A guide to managing knowledge*. Harvard Business School Press: Boston.

WENGER, E. (2004a). *Cultivating communities of practice: A quick start-up guide* [online].
Available from: http://www.ewenger.com/theory/start-up_guide_PDF.pdf

WENGER, E. (2004b). *Communities of practice: A brief introduction* [online].
Available from: http://www.ewenger.com/theory/index.htm

YEH, A. (n.d.). *NKFUST's listening and conversation class with Michael Coghlan* [online].
Available from: http://www.geocities.com/aidenyeh/michaelc/fear_of_being_too_good_audio/index.htm

Integrating critical cognitive skills in the IT curriculum of the first year developmental programme of UAE University: Issues, experiences and challenges

Tago Ranginya and Paul McKenzie

University General Requirements Unit, Al Ain, United Arab Emirates University

Background and overview of the ICT curriculum

Until recently, students in the University General Requirements Unit (UGRU) have been learning fundamental information technology (IT) skills more as a matter of training than education. This typically entails a heavy emphasis on learning 'how-to' skills of office-software applications, with success being measured by how well (and how quickly) students are able to manipulate specific application features. Unfortunately, this method of teaching and learning IT has fallen out of step with the intellectual and technological needs of modern university students in a first-year developmental programme. As the number of students arriving at the United Arab Emirates University (UAEU) already in possession of these IT skills has grown, so has the idea that their educational needs would be better served by teaching and learning practices that integrate technical and critical cognitive skills. This reflects a growing consensus worldwide that IT be envisioned not only as a set of tools to be learnt but as a set of skills for life-long learning, communication, information management, and problem-solving. As of the Spring 2005 semester, a new IT curriculum at UGRU has been attempting to put this vision into practice.

Work on the new curriculum began in March 2004, when an UGRU task team was mandated to spearhead its design and implementation. The goal was both clear and ambitious: launch a new IT curriculum that helps UGRU students learn both the technical and the critical cognitive skills relevant to a first-year developmental programme, thereby better preparing them for university life and beyond. UGRU Dean Dr Abdullah Al-Khanbashi shrewdly realised this would have the added benefit of filling in gaps that existed between the existing IT curriculum and the UGRU Conceptual Framework – the document defining the knowledge, skills and dispositions students should have when exiting UGRU. Because the IT curriculum was based on that of the International Computer Driving License (ICDL) programme, it was devoid of the sort of

cognitively-oriented competencies characterising the UGRU Conceptual Framework – learning skills, thinking skills, communication skills, information literacy, and knowledge application. These cognitive competencies would find a prominent place in the new UGRU IT curriculum, however.

In order to ensure the new curriculum would meet the needs of students in a first-year developmental programme, the task team first looked at what other educational jurisdictions are doing in this regard. What they found was a growing consensus on the need to promote not just technology learning but technology literacy, to settle for nothing less than the goal of having this media-savvy generation of students become functionally capable and comfortable with both information and communication technology. It goes without saying that we live in an increasingly digitised world of knowledge and communication. We owe it to our students to prepare them well for that world.

With this background in mind, the task team decided first of all to adopt a new name for the new curriculum. The name Information and Communication Technology, abbreviated as ICT, was decided on for two reasons: first, it better reflects the new curriculum; second, this term is becoming increasingly used worldwide to describe the digital realm. Next, the team came up with six learning areas around which the new curriculum would be built. These six learning areas are intended to build on each other to form a spiral of learning experiences for students. Figure 1 shows a conceptual diagram of the learning areas and how they are related.

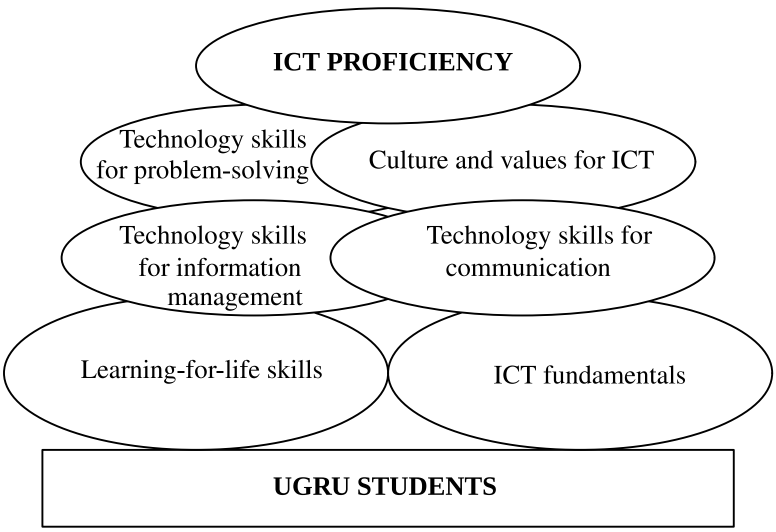


Figure 1: ICT learning areas. This conceptual diagram was designed by Paul McKenzie, one of the members of the task team.

In these six integrated learning areas, learning ICT tools, rather than being an end in itself, becomes the means of developing both technical and cognitive skills. Instead of simply learning how to use a specific operating system, word-processing, web-browsing, or spreadsheet software package, students learn how to use tools such as these to help them access, acquire and assess information; advancing their communication and information management skills; and solve real-world type problems. Attention is also given to learning-for-life skills, as well as culture and values as they pertain to the use of information and communication technology.

These six learning areas provide the organising structure for both semester-long courses that make up the IT programme. The content differs, of course, based on progressive ICT skill and knowledge acquisition. Methodologically, ICT1 and 2 are taught (and learnt) mostly through the use of real-world, scenario-based tasks (either individually or collaboratively) and was in sharp contrast to the daily worksheets of the old curriculum. The same contrast characterises assessment. Whereas in the old curriculum, tests and examinations consisted of narrow demonstrations of technical proficiency, in the new curriculum students demonstrate cognitive as well as technical proficiency by completing real-world, scenario-based tasks requiring a broader skill and knowledge base. Marking is done with rubrics rather than checklists, so as to more accurately gauge overall student performance.

Integrated proficiencies in the ICT curriculum

The ICT curriculum emphasises intellectual development as much as, and in some cases more than, IT-skills development. While the use of ICT tools still forms the basis of daily classroom activity, academic enrichment is added by the inclusion of elements requiring critical cognitive skills, thus better preparing students for university life and beyond. For instance, students are required to collect, organise, manipulate, and evaluate data for the purpose of making recommendations about such things as which model of car to purchase for a taxi fleet or which hotel to stay at while on holidays in a given country or city. Students entering UGRU already in possession of IT skills thus find that this curriculum provides cognitive challenges useful in preparing them for advanced study and beyond. Students lacking technical skills will still learn them, but they do so in the context of scenario-based tasks that develop both their technical and cognitive skills.

Figure 2 shows how the integration of technical and cognitive skills promotes the ICT proficiency characteristic of ICT literacy. Technical skill represents the effective use of software tools; cognitive skill represents the purposeful application of intellect. ICT literacy represents the effective use of software tools *for a real-world purpose and outcome*. By combining the two skill-sets, students coming out of the IT programme will be able to perform successfully the knowledge-based activities below:

- **Access**: Knowing about and knowing how to collect and/or retrieve information

- **Manage**: Applying an existing organisational or classification scheme.
- **Integrate**: Interpreting and representing information. This involves summarising, comparing and contrasting.
- **Evaluate**: Making judgments about the quality, relevance, usefulness or efficiency of information.
- **Create**: Generating information by adapting, applying, designing, inventing, or authoring information.

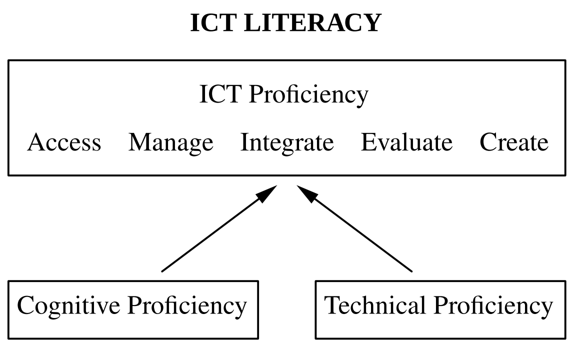


Figure 2: Digital transformation: A framework for ICT literacy (Educational Testing Service, 2001).

Scenario-based tasks in the ICT curriculum

Assessment tasks in the old curriculum typically consisted of narrow demonstrations of technical proficiency. In the new curriculum, students demonstrate cognitive as well as technical proficiency by completing scenario-based tasks that require a broader skill and knowledge base. Below is an example of a relatively simple assessment task.

Sample ICT task
Students in an ICT class have been asked to provide information about the popularity of the subjects they study in UGRU: ICT, English, Mathematics and Arabic. Students are required to send this information by e-mail to their teacher and classmates.

This task can be further divided into two sub-tasks as follows:
Sub-task 1
Create an address book containing the e-mail addresses of all students and the teacher.
Sub-task 2
Send an e-mail to the teacher and classmates indicating the survey results. Students are to include their own opinion and give reasons for their rankings.

Assessment
Using the ICT proficiency components shown in Figure 2, students would be assessed using the following criteria:

ICT proficiency	Tasks
Access	*Select* and *open* appropriate e-mails received from inbox list.
Manage	*Identify* and *organise* the *relevant* information in each e-mail.
Integrate	*Summarise* the number of dislikes and likes using an appropriate application.
Evaluate	*Decide* which subject is the most liked and which one is the least liked.
Create	*Write* an e-mail to the teacher indicating the popularity of the various subjects. *Attach* any relevant tables or charts.

Challenges for the ICT curriculum

The challenges faced by the IT task team have to be seen within the larger context of recent changes at UGRU, which are being driven by a new vision of its role within UAEU. A major objective of these changes is to turn UGRU into a more dynamic developmental programme, which takes greater account of the changing academic needs

and abilities of its clientele. It was on this basis that the UGRU Conceptual Framework was developed and is now being used to standardise key pedagogical elements across the disciplines of English, Arabic, Mathematics, and IT.

The first challenge, then, was to find or develop an IT curriculum model that would enable us to bring our curriculum into closer alignment with the UGRU Conceptual Framework. The work of the International ICT Literacy Panel, sponsored by the US-based Educational Testing Service, greatly assisted us in meeting this challenge. It provided a framework for integrating the critical cognitive skills of the UGRU Conceptual Framework with the technical skills of the existing IT curriculum.

It took some time, however, to design and write a course competencies document detailing the actual integration of cognitive and technical skills. The UGRU Conceptual Framework competencies of communication, information literacy, and thinking skills were roughly and partially mapped over into ICT course competencies of communication skills, information management, and problem-solving. For the sake of expediency, somewhat arbitrary distinctions were made designating word-processing, presentation and e-mail applications as communication tools; web-browsing and database applications as information management tools; and spreadsheet applications as problem-solving tools.

Pacing and sequencing the material provided additional challenges. It was difficult to gauge whether the students would move through the material more quickly (because of increased interest in the scenario-based, real-world tasks), more slowly (because of the greater complexity of the tasks and, in particular, increased language demands) or at about the same pace as in the old curriculum (early results suggest they move through the more material more quickly due to increased interest). And in what order should the material be presented? Operating system fundamentals provide a fairly natural starting place, but where to go from there? Communication skills? Information management? Problem-solving? Our familiarity with the United Arab Emirates public-school curriculum suggested we should begin with what our students are most familiar with – word-processing and presentation software. So, communication skills were introduced first, followed by information management and then problem-solving. This has the added benefits of allowing students to get used to the task-based curriculum while working with more familiar tools, as well as fostering early success to build confidence for the more difficult work ahead.

Developing tasks for the new curriculum was the next challenge faced. Task development criteria were based on the five-point definition of ICT literacy developed by the International ICT Literacy Panel, stipulating that the measure and end result of ICT literacy should be the ability to ‘access, manage, integrate, evaluate, and create information’. Using these criteria, the task team solicited input from all IT teachers. The results were numerous and gratifying, suggesting teachers were buying into the change in philosophy entailed by the new curriculum. Sufficient tasks were developed prior to the pilot offering to get started. Once underway, teachers began creating their own tasks and sharing them with each other. This greatly enriched the content of the

pilot.

Finding a suitable textbook for the new curriculum proved to be an elusive undertaking. Nothing even close to what was wanted could be found in time for the pilot offering. Negotiations with a textbook publisher are currently underway to have a text written specifically for our needs. Meanwhile, we continue to provide ICDL materials to the students, so they can learn and practice the technical skills required for them to accomplish the required tasks. The task descriptions themselves were assembled and printed with the ICDL material, so as to give the students a single text. This text is emphatically not a teaching manual, however, as some teachers found out the hard way by initially trying to use it as one.

Teacher acceptance, orientation, and preparation were the remaining challenges prior to rolling out the pilot offering of ICT1. While teachers were enthusiastic about adding academic enrichment to the IT curriculum, they rightly wondered exactly what sort of changes this would entail for their daily regimen in the classroom. The course competencies and performance objectives, where new cognitive elements were grafted into the curriculum, were often too abstract or too general to give them clear direction. Conversely, most of the teaching and learning objectives, drawn from the ICDL curriculum, were all too precise and familiar, making it seem like it would be business as usual in the classroom. Task team members inadvertently added to the confusion by saying with great zest things like ‘We’re not teaching MS Word anymore; we’re teaching communication skills!’ ‘So what software are we using?’ teachers would ask, bewildered, since they had not heard there was to be a change in software. ‘Oh we’re still using the same tools’, would come the equally puzzled reply, twisting the poor teachers further into knots until the distinction was made sufficiently clear.

Pacing and sequencing documents, as well as orientation workshops, helped prepare teachers to pilot the new curriculum on schedule, but it took time to make the philosophical and practical transitions in the classrooms. Should teachers continue to use worksheets to help students gain rudimentary skills before launching into scenario-based tasks, or should they use the tasks themselves as the means to teach those skills? Both were tried, but it seemed as if there was sufficient learning embedded in the tasks themselves, as it were, for the teachers to abandon the old worksheets and let the tasks lead the way.

Increased intellectual demands naturally fell on both teachers and students as the pilot progressed. On the former, to *explain* and utilise the more sophisticated thought processes required by the new curriculum; on the latter, to *understand* and utilise those same thought processes. Naturally, too, this entailed increased language demands on the students. This was compensated, however, by the real-world-scenario-style characterising the tasks. Teachers chose features of everyday life, or at least related the tasks they chose to such features. Increased student interest in the material smoothed the transition to the task-based curriculum.

The most recent challenge to arise has been that of assessment, in particular the mid-term and final examinations. Clearly, multiple-choice question testing was not a

viable option for such a performance-oriented curriculum. But with a one to one-and-a-half hour time frame for examinations, could assessments be devised that would allow students to demonstrate both technical and cognitive proficiency, using and integrating multiple applications to do so? In the end, it was decided that scaled-down tasks would be used, and rubrics would replace the checklist method of marking performance in the old curriculum. Despite having several rubrics workshops before the first ICT1 mid-term, however, the first rubric-calibration session did not take place until after the examination. In hindsight this should have occurred much earlier, as significant differences in marking philosophies surfaced all over, and much compromising had to be done to come to a general consensus as to how to mark the mid-term. An excellent collegial and professional spirit infused the proceedings, however, and subsequent spot-checking proved the compromises were sincere. Valuable lessons were learnt that will stand us in good stead for the upcoming first ICT1 final examination.

Challenges will always accompany a change in curriculum. For an IT curriculum, the challenges are compounded by the pace of change in the IT field itself. But by making the new UGRU ICT curriculum more academic and less tool-specific, the task team hopes at least to increase its 'shelf life'. More importantly, however, it is our hope that the new curriculum will better meet the academic and intellectual needs, and help fulfill the personal and professional aspirations of twenty-first century UAEU students.

Reference

EDUCATIONAL TESTING SERVICE (2001). *Digital transformation: A framework for ICT literacy* [online].
Available from: http://www.ets.org/research/ictliteracy

General

Tips and techniques for designing learning assessments and activities

Nancy Schley

Madison Area Technical College, Madison, Wisconsin, United States of America

Introduction

When developing curriculum, we follow the principles of Performance Based Learning (PBL). This principle of learning relies on performance or demonstration of the application of skills, knowledge, and attitudes, and measures the learner's achievement based on performance standards as developed by the teachers. This strategy allows learners to progress only when they have achieved the stated goals. It also holds learners and teachers accountable for the achievement of the intended outcomes.

The design and measure of performance

To measure this performance adequately, we need to determine performance expectations for learners, design assessments that measure performance, and then align performance expectations, assessments, and learning activities to ensure the learner is prepared for assessment of the competencies. The performance-based-learning curriculum development model can be used to assist in the development of aligned assessment tasks and learning activities to include:

- Specify assessments strategies
- Develop assessment criteria
- Write learning objectives
- Design learning activities
- Select learning plan prerequisites
- Develop instructional materials

After we have developed the course competencies, linked programme outcomes, and core abilities, and established the learning hierarchy flowchart, we are ready to consider how we are going to assess the learners in the course. Notice that we prepare the assessment tasks before we talk about what will be going on in the classroom. This way we can keep the 'end in mind' as we later prepare learning activities for the learners. Assessment means ongoing, individualised feedback given in a constructive manner for continual improvement. We believe that learners learn better when they receive continuous feedback about their progress. Evaluation is closure, the final grade, if you will.

We write the instrument or measurement that will used to assess each competency (called a condition). We determine this condition by answering the following questions: 'How will my learners show that they have achieved the competency?' and 'What will I use as a measurement to assess the competency?' Examples of conditions may include: case study, class participation, oral presentation, written product, investigative report, journal, lab report, informational interview.

Only then can we write the criteria for assessing the condition. The criteria describe satisfactory performance and provide the basis for judging whether or not the performance is acceptable. This is a difficult part of designing learning so we put a great deal of time and emphasis into writing the criteria. We must tell the learners how their performance will be judged. We give them this information before the assessment (even at the beginning of the course). By clearly telling the learners the expectations for acceptable performance, there are no surprises and there is no more guessing on the part of the learner as to what the teacher expects. When the learners do not achieve, they are empowered to assess their own work and make corrections or seek assistance prior to evaluation. For teachers, the criteria offer a precise measuring tool for assessing and evaluating achievement consistently and documenting accountability.

> Examples of criteria are: 'You select an issue that is important and relevant to each institution'. 'You outline a personal position on the issue'. 'The presentation purpose is clear'. 'The presentation includes an introduction with an overview of the main points'. 'The presentation includes a conclusion'.

Next we create the performance assessment task. The performance assessment task is the assignment that learners do to demonstrate achievement of the competency(ies). Performance Assessment Tasks increase the validity, reliability, and fairness of assessment based on consistent criteria and grading rubrics. We write a statement that directs the learners to complete a task or assignment (this is directly related to the condition and core ability statements that are already recorded). A rating scale is applied to the criteria already written into a scoring guide. The rating scale is a pre-established, fixed value used to differentiate among levels of performance. The learners can self-assess their progress using this scoring guide and revise their work as necessary. The teacher uses the scoring guide to evaluate the learners' work and to provide feedback to the

learner.

The design of learning activities

Now, finally we can get into the classroom and design the learning plans consisting of learning objectives, learning activities, and instructional materials that prepare the student for assessment and/or evaluation. The learning plan creates a structure that learners can follow; is a clear connection between competencies, learning, and assessment; and is communicated to the student at the beginning of the lesson or course.

We begin by designing learning objectives that guide the learners through what is going on in the classroom. These reflect measurable and observable supporting skills, knowledge, and attitudes needed to perform the competency. Then we design the learning activities to guide learners through the learning process. The learning activities provide a step-by-step guide to the learner through the learning experience. They are learner-centred, require frequent practice, include a variety of learning/teaching strategies, and relate directly to the competency.

Learning activities follow a specific learning cycle: motivation, comprehension, practice, and application. The learning cycle begins with a motivation activity that inspires learners to learn. This activity answers the learner question, 'Why do I need or want to learn this material?' This activity provides learners with an opportunity to sense and feel the competency and build their own reasons for achieving it. Examples of motivation activities may be: share personal experiences, brainstorm why it is important to learn the competency, suggest solutions to a problem.

Next we develop a comprehension activity. This activity presents the student with information or questions pertaining to a concept. It is important to select a variety of comprehension activities that cognitively challenge the learners' brains. Brain-based research encourages the teachers to ask unanswered questions allowing time for the learners to think about the answer and draw their own conclusions.

This comprehension activity is followed by learner practice in applying the presented information to encode it into long-term memory. This comprehension/practice section of the learning cycle is repeated until all information in the lesson has been covered. Throughout the cycle, it is important to note that the part the teacher plays is to facilitate learning by selecting activities that actively involve the learner. A broad choice of activities should be selected to accommodate various learning styles. This means that we consciously avoid the traditional lecture, read, question, and test for information process. That does not mean we eliminate the former. Instead, it means that it is important to vary the pattern to include participative learning activities that offer learners the opportunities to work in their preferred mode of learning. Built-in opportunities for feedback to the learners are a natural and necessary part of the activities. These allow for adjustment of teaching methods and learning strategies.

Including demonstrations, simulations, investigations, guided practice, projects, feedback, memory aids, graphic organisers, information seeking, information receiving,

teacher-directed reading, and learner-directed reading are all examples of different learning activities. We can also vary the learning environment to include classroom, lab, community, and workplace. We can vary activities to include individual and collaborative learning activities that call for interpersonal contact such as working in pairs, small groups, or large groups. It is important to allow learners to draw on their own experiences for relevant examples and problems, identifying patterns that help to make sense of incoming information. Finally, we can vary the media such as computer simulations, computer-based lessons, computer-based practice, satellite conferencing, the Internet, audiotape, radio, transparencies, slides, flip-charts, video, demonstrations, manipulations, models, and hands-on practice. We can include guest speakers, panels, and fill roles as coach, facilitator, learner, presenter or questioner. This comprehension/practice section of the learning cycle is repeated several times until the information to be presented in the lesson is complete.

Another way to look at learning activities is through the selection of learner participation activities that meet the four basic psychological needs; belonging, freedom, power, and fun (Glasser, 1984). We select activities for belonging by sharing and talking with others, encouraging group discussions and sharing among students. Prefacing comments with a student's name or by sending private messages to students who are not talking helps to relieve stress on the learner. We all have a need to connect with others, establish friendships, and know others care about us.

Activities for freedom allow for flexibility and choices regarding assignments, encourage discussions and sharing of thoughts and ideas, allow for making choices of when and how to complete an assignment, and choosing whether or not to explore a topic of interest in more depth. We all have a need to act and think without restrictions by others. To allow freedom means to say, ‘I choose’, ‘I want’, ‘I will’.

Activities for power require learners to think and involve discovery learning, by encouraging learners to share ideas and explore new ones, and by encouraging them to utilise their best skills and to share their personal knowledge with others. It is important to each of us that others recognise us for what we do say and by what we do.

Activities for fun encourage students to excel by holding contests, using graphics, jokes, riddles, etc., encouraging co-operative learning because learning together is fun, creating interactive discussions and group work, having learners produce creative projects. We all need to accomplish a challenging task successfully, be entertained, and take-part in significant and meaningful learning experiences.

The learning cycle is completed with an application exercise that allows the learners to apply what they have learnt to real world situations. Here the learner gets an opportunity to experience or conceptualise how all the pieces fit together.

One example

An example of the use of the *Learning Cycle* involves my own work when I taught at the United Arab Emirates University. I would clearly spell out the learning objectives

at the top of the page on worksheets and assignments. Then I would write three progressively more difficult worksheets covering the same objectives. The first worksheet included a step-by-step progression the learners had to follow. I also had a copy of the finished product at the bottom of the page so the students could check their own work for correctness and completeness. The second worksheet, a companion to the first, required the student to complete a similar problem to the one on the first worksheet but with no steps listed. If the learners had difficulty completing the task, they could refer back to the first worksheet and follow the steps to complete the second worksheet. The finished product was again at the bottom of the page. The third worksheet in this trilogy, supporting the same learning objectives, was written in the form of a scenario with no finished product. The learner had to study the problem and come up with his or her own solution. I was constantly striving for activities stressing critical thinking that were ever more progressively difficult, demanding higher order thinking skills. The learner therefore established a pattern and could make predictions based on previous conditions or experiences in earlier worksheets. To teach the class, I wrote my learning objectives in a brief format on the board. Above the objectives, I wrote the Learning Plan Prerequisites (homework). As I taught the class, I would walk to the board and point to the objective that I was covering. The students could clearly follow where we were at any specific time in the lesson and could also see how each objective fitted with the next. Before I went on to the next objective, I would summarise the just completed one. At the end of the lesson, I would take a minute to summarise the entire lesson. So, consequently, I would follow the adage: ‘Tell them what you are going to teach, teach it, and then tell them what you taught’.

I then broke down the lesson into smaller sections. I taught the class with a short demonstration in the first section followed by a practice session. Then I repeated this procedure until all the sections were completed. Thus, the first worksheet in the trilogy was completed. As the students completed the second and third worksheets in the trilogy, they were in the application phase of the Learning Cycle.

Conclusion

In conclusion, by creating and distributing to the learners the Performance Assessment Tasks including conditions and criteria, the learners see how they will be evaluated and can focus their time and energy on preparing better performances or products and self-assess their work before submitting it for formal evaluation or marking. In doing so they are more likely to perform according to the teacher’s expectations. The Learning Plans, including learning objectives and learning activities, link *what* learners will learn with *how* they will learn and *when* they will know they have achieved competence.

References

Accelerated learning course builder (1999). The Center for Accelerated Learning: Wisconsin.

ANGELO, T. A., CROSS, K. P. (1993). *Classroom assessment techniques: A handbook for college teachers* (2nd ed.). Jossey-Bass Publishers: San Francisco.

GLASSER, W. M. D. (1984). *Control theory*. Harper and Row: New York.

MASHBURN, D. AND NEILL, J. (2002). *WIDS learning design system user's manual* (Version 7). The Wisconsin Technical College System Foundation, Inc.: Wisconsin.

SCHLEY, N. (2005). *Website for instructional design* [online].
Available from: http://matcmadison.edu/is/iss/etla/curriculum/

STIEHL, R. AND LEWCHUK, L. (2002). *The outcomes primer: Reconstructing the college curriculum*. The Learning Organisation: Oregon.

STIEHL, R. AND LEWCHUK, L. (2005). *The mapping primer: Tools for reconstructing the college curriculum*. The Learning Organisation: Oregon.

WESSON, K. (2004). *The latest research on the biological basis of thinking and learning*. Paper presented at the 11th ASM Conference for Undergraduate Educators, May 21–23.

Enabling students to cope with information overload: The mind map technique in secondary and higher education

Farid Benyahia

Department of Chemical and Petroleum Engineering, United Arab Emirates University, Al Ain, United Arab Emirates

The end of the twentieth and beginning of the twenty-first centuries have been characterised by an explosion in information. Thanks to the spectacular expansion in Information Technology, most of this information has been able to find its way into virtually all aspects of life, not least in education. However, whilst the volume of information available has increased by many orders of magnitude, the amount of information related to the fundamental laws of physics, chemistry, and other basic sciences is relatively modest. What has changed, however, is the spectrum of applications that exploit such fundamental laws. This has undoubtedly created a great deal of problems to students in terms of knowledge retention in classic science subjects that increasingly contain new applications, thus making the subjects overloaded compared to former times. In this paper, a knowledge retention technique called the 'mind map' technique is presented with an example of successful implementation in chemical engineering education in the United Kingdom and the United Arab Emirates. This technique has proved to be useful in enabling students to cope with information overload in a variety of subjects and can in principle be applied to pre-university or university education.

Introduction

The end of the twentieth and beginning of the twenty-first centuries have been characterised by an explosion in information. Thanks to the spectacular expansion in Information Technology, most of this information has been able to find its way into virtually all aspects of life, not least in education. In the so-called 'heavy' subjects of science and engineering, students are expected to understand and retain knowledge in all its forms:

fundamental principles, models, applications, etc. How does the student face this challenge? Obviously, their first encounter with these 'heavy' subjects are in the form of lectures, tutorials, laboratories and assignments. Beyond these, a growing proportion of students tap into the Internet in the hope of finding some 'magic' formula that will enable them to understand what they failed to grasp in lectures, and perhaps provide them with a good background coverage for their essays, reports, or similar assignments. This is an established and verifiable fact. However, those educators who really monitor closely their students' progress find that they often overload themselves with superficial, irrelevant, or even confusing information. It is not difficult to understand why. Figure 1 clearly shows that while general online information increases exponentially over time, the amount of new knowledge increases more modestly. Therefore, the ability to screen accessed or downloaded information becomes critical. By far the best way to guide students into relevant and useful literature searches for major assignments is to equip them with good, concise teaching material that will enable them to understand and assimilate those fundamental principles, underlying theories, and major applications which are considered important.

With the above issues in mind, one can ask a legitimate question: do we really understand our students' learning styles? Do we address their specific needs or do we just follow a routine we experienced perhaps in our own education? These matters are absolutely crucial for training students to train themselves. In the next section, an extract of studies on learning styles is outlined as it constitutes an important element of this paper.

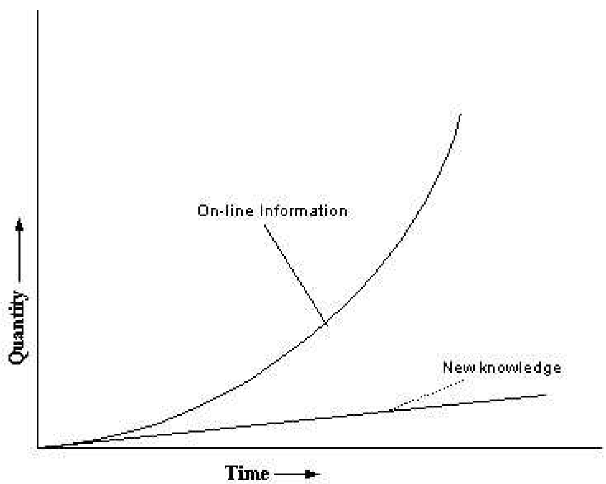


Figure 1: Trend of online and new knowledge over time.

Students' learning styles

Recent studies have shown that the student learning process incorporates learning dimensions and learning styles. The learning dimensions have been reported as; processing, perception, input, and understanding. In each dimension, these studies have shown that students can belong to different categories of learning. Briefly, these are:

1. **Processing**
   (a) Active learner: learns best by doing something physical.
   (b) Reflective learner: tends to do processing in the head.
2. **Perception**
   (a) Sensing learner: prefers data and facts.
   (b) Intuitive learner: prefers theories and interpretation of factual information.
3. **Input**
   (a) Visual learner: prefers diagrams, charts and pictures.
   (b) Verbal learner: prefers spoken or written word.
4. **Understanding**
   (a) Sequential learner: tends to make linear connections between steps.
   (b) Global learner: must see the overall picture before individual pieces fall into place.

From these studies, one can clearly see that traditional lecturing styles will not satisfy the learning needs of most students. This situation will be exacerbated if the student who feels left out in lectures attempts to learn from 'other' sources (principally from the freely available literature on the Internet), thus falling into the information overload trap referred to in the introduction. There is therefore a clear case for diversifying teaching delivery patterns. But first, let us explore how information is retained.

Knowledge retention

From the literature on knowledge retention, Figure 2 depicts a classic pattern that seems to apply to most people. In particular, in education this is particularly true; within a short period, most students have forgotten most of the material delivered in lectures.

In order to shift the retention curve upwards, we recommend that taught material is regularly revised over a period of time (see Figure 3). The more frequent the revision process, the more likely knowledge will be retained. However, realistically, students cannot be expected to spend hour upon hour revising dozens of pages of lecture material for four or five different subjects. In that case, what should they do? This question

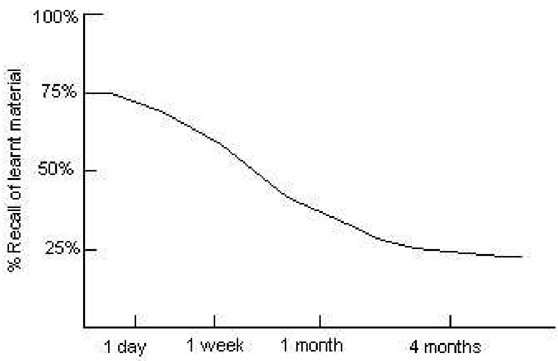


Figure 2: Typical knowledge recall curve over time.

has obviously been the subject of a great deal of discussion and research. In the last decade or so, Buzzan (1998) proposed a knowledge retention method which he called the 'mind map'. It consists of organising information to be retained in a non-linear fashion, compatible with the way our brain seems to work. We all know that most students learn in a linear fashion, reading through the teaching material sentence by sentence and often trying to memorise the whole content in a desperate attempt to score high marks. The student with a poor memory, especially long-term memory, is often the first casualty of such a poor practice.

Research in the area of knowledge retention has shown that memory works associatively, in other words, knowledge is stored when it is understood. It is therefore clear that memorising without understanding is the principal reason for poor performance in courses.

Rather than memorising hundreds of pages of teaching material, a much more effective approach would be to memorise essential, key information only. This would be within the ability of any average student. Thus, Buzzan's approach is first to identify essential keywords of direct relevance to the subject matter. He defines two types of keywords, namely 'recall' and 'creative'. The former triggers the same mental image, thus specific information, whilst the latter triggers a range of images, thus general, evocative information. These two concepts have to be explained clearly to students learning the mind map technique, with generous examples provided.

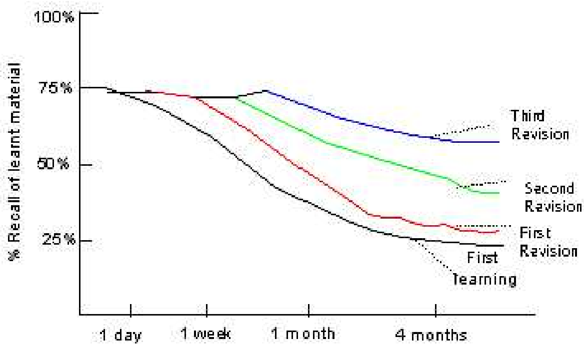


Figure 3: Recall curves following several periods of revision over time.

The mind map concept

The mind map technique consists of first identifying exhaustively keywords of relevance to the subject matter (say one particular scientific course, or a theme in an assignment) and then organising them into a cobweb fashion such that the central keyword would be the title of the course, theme, etc., and with immediately relevant words branching outwards from the keywords.

In order to master this technique, a great deal of practice is necessary (Kolb, 1984). In practical terms, this is best approached as a team exercise where a series of mind maps of the subject under consideration are designed and refined recursively. What is the benefit of doing all this? Referring to the large volume of information students currently have to cope with, it is clear that retaining a few keywords arranged in a special way would be a great deal easier. The advantage of this approach would also enable the student to express themselves in their own words by building on these keywords rather than regurgitating information given to them by either the teacher or memorised from their texts. In practically all cases, all courses without exception can be summarised on a single A4 sheet as a mind map which can be used for revision purposes.

Experience in employing the mind map technique in chemical engineering education

The concept of the mind map has been employed successfully by the author to teach ‘heavy’ subjects in chemical engineering for a number of years in both the United Kingdom and the United Arab Emirates. These include the tough ‘Process and Plant Design’ course often associated with information overload (Benyahia, 2005). Initially, the course mind map was based on a simple text which was subsequently modified electronically to keyword hyperlinks that expanded on detailed pages, and ultimately

the hyperlinks would be connected to text, graphics (still or animated) and audio. It is believed this would make revision for a mind map based course much more effective and enjoyable. This approach also addresses the issue of varying learning styles. Hence those students who are more geared towards learning visually would benefit from any graphics or animations, just as those who prefer to listen would be satisfied to hear verbal information in addition to textual information. Figure 4 depicts a text based mind map used for the Process and Plant Design course. A web based equivalent with text hyperlinks is also available (see Benyahia, 2005).

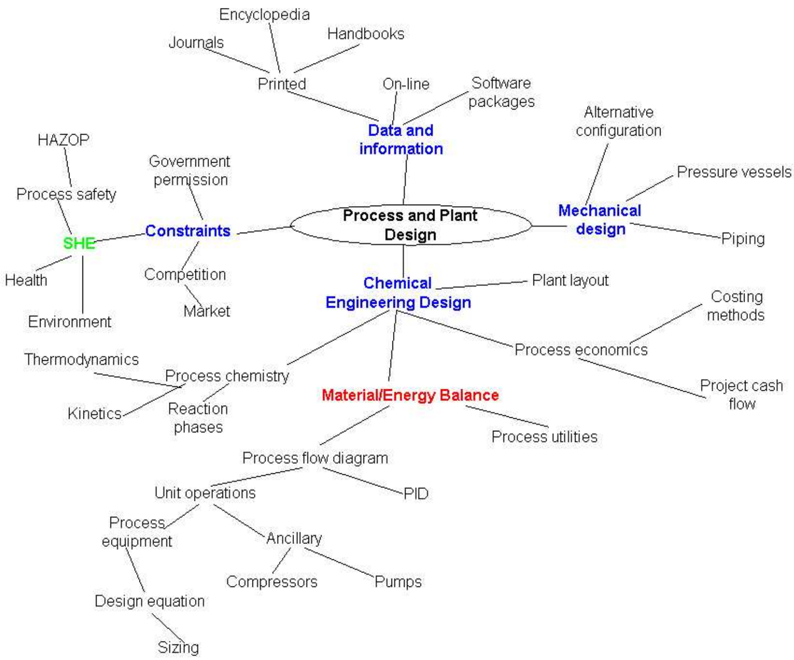


Figure 4: Process and Plant Design course summarised as a mind map with hyperlinked keywords.

The mind map is ideally introduced after the mid-term examinations when students have accumulated enough knowledge in the course so as to build incrementally a substantial course summary.

Conclusion

The issue of information overload in secondary and higher education is serious enough to warrant consideration. In assisting students to move away from superficial surface

learning towards a deeper approach to learning, an effective tool based on mind maps is highly recommended. The method can be very powerful, particularly if coupled to hyperlinked multimedia material. It is also just as effective on paper. In assisting in establishing students' preferred learning styles, a simple questionnaire followed by an analysis based on responses can be readily found (see, e.g., Felder, 2005). The responses can be used to design more effective lecture delivery patterns based on more sophisticated mind maps.

References

BENYAHIA, F. (2005). *Teaching materials*. [online]
Available from: `http://www.engg.uaeu.ac.ae/farid.benyahia/`

BUZZAN, T. (1998). *Use your head*. BBC Consumer Publishing: London.

FELDER, R. M. (2005). *Learning styles determination website* [online].
Available from: `http://www.ncsc.edu/felder-public/`

KOLB, D. A. (1984). *Experiential learning*. Prentice-Hall: Englewood Cliffs, NJ.

Not to extinguish the creative spark in our students

M. Odeh

Mathematics Program, University General Requirements Unit, United Arab Emirates University, Al Ain, United Arab Emirates

In this paper I describe an after school activity, namely the generic quiz, that I have implemented in one of my basic algebra classes. In this activity students are asked to make up a quiz and its solution key. The generic quiz is an activity that motivates students to practise their experience in problem-solving from a different point of view as they come in control of creating an assessment of what they are supposed to know. I have shown also how students must be trained to get the full benefits of this activity. Samples of student generic quizzes are presented and analysed to investigate student cognition and attitudes towards a departure from the traditional, deep-seated assessments students are current familiar with.

The generic quiz

The traditional lecture/homework/quiz format of teaching proves efficient in presenting a large amount of material in a limited time. In certain cases, it is the only way to get a satisfactory answer for the end of semester or pre-examination question, 'Did you cover the syllabus?' Under pressure from such questions, we teachers continue to cover the syllabus pretending that our students learn the same as what we intend to teach. Unfortunately, while efficient, this format has never been shown to be effective at producing critical and innovative thinking skills. If we are to nurture critical and creative problem-solving and thinking skills, we have to depart from this traditional way from time to time. We have to provide, periodically, opportunities to exercise these skills. Our classroom atmosphere must lend itself to the accommodation of such exercises, recognition of these skills, and encouragement of those who display talent along these lines. Ultimately it is our responsibility to produce creative students, or at least not to extinguish the creative spark in them.

The literature is rich in approaches that develop creative problem-solving and thinking skills (Woods, 1983; Arnold, 1962; Barron, 1981; de Bono, 1970). However, the

critical issue is to select appropriate activities that will not overload both teacher and student. These activities should not take up too much of class time, as the requirements of the syllabus still need to be met. Moreover, a method, whatever its pedagogical soundness and potential benefits are, will probably not be implemented if it takes a great deal of teacher time and effort.

In this work, I attempt to apply a simple technique that puts these skills to practice, namely the generic quiz (Felder, 1985; Felder, 1987). Here students in an elementary algebra course were asked to write a quiz of five questions, and solve them. This task is assigned to students as a take-home quiz over the weekend (in fact, it was a long weekend as we had a national holiday), and somehow minimised communication between students, thus reducing duplicates. As students hate playing innovative games without knowing the rules, I distribute a list that includes the assignment, rules of the game, and the standard format of the quiz before assigning such a task.

Of course, this assignment was not a totally new experience for students. In order to get the greatest benefit from such an activity, the ground rules should be laid down prior to the assignment being given. Students should be trained to reflect on their learning by formulating problems related to things they have learnt on a regular basis. Moreover, students should be able to recognise the different levels of thinking that may be involved in making up and solving a problem.

During the weeks before the generic quiz assignment, I selected a student at the end of each lecture after I covered a new objective and assigned him/her to write a *challenge problem* about the topic of the lecture. The student was given roughly two days to come up with a problem. The problem was then presented by the student during the class. Other students were asked to discuss it, suggest ways to improve it, and include any additional ideas. During the discussion, I try to play the role of a facilitator and let the student who wrote the problem defend his work. However, I try always to draw students' attention to the main components that should be included in a problem. I show them how a problem can be sliced into *background information*, give *data* and *things required to be found*. At the beginning, it was clear that most student problem structures were very poor. I had to spend some time just to show how data should be presented in the problem and how it should match requirements. During the second week, one student prepared the problem shown in Figure 1.

$$A = \{2, -1, 3.4, \pi, \sqrt{11}\}$$

1. Natural numbers	3. Rational numbers
2. Integers	4. Irrational numbers

Figure 1: A problem prepared by a student during the second week of semester.

Clearly the student was missing a basic structure to the problem. The problem should have stated '*Given* A', as a reference for what is required. The problem did not say '*Find*' or '*List*' parts a, b,...etc. The student assumed that as we were dealing with this kind of problem of listing and recognising different types of numbers in class, it would be obvious that you needed to list the different types of numbers required in parts a, b,...etc. Six weeks later, the same student presented the problem shown in Figure 2.

Solve the following inequality *for* x and graph its solution set.

$$3 - (2x + 1) \geq x - 4.$$

Figure 2: A problem prepared by the same student as in Figure 1 during week eight of the semester.

Comparing the second problem with the first one, the difference in structure is obvious. The second problem includes all parts of a standard, well-written problem: action to be taken 'solve' and 'graph', information to be used 'the following inequality', and further manipulation of the result of the main action 'and graph its solution set'. It was very clear that the student picked up the basic idea of how to implement things he/she had learnt to make up a good, well-structured problem.

Students' feedback on such an activity was, (i) it motivated them to think deeper than when just memorising, (ii) it forced regular revision of the material, (iii) it helped them when attempting to solve a problem because they already knew that there should be data and action to be taken, (iv) it created discussion between students where every student had the chance to express verbally what he had learnt and helped some to better understand things they missed, and (v) it gave students insight into how teachers write tests, thereby helping them to over come normal pre-test fears.

At the point when I felt students had become more aware, responsible, and ready to play a new game, I gave out this assignment. Students' impressions and reactions to this activity varied from 'Oh God, not again!' to 'Great! This time I am going to show him that I am the best'. In fact, whatever you do, students' discomfort is always unavoidable. And if 20% of students do not participate seriously, then at least you have 80% of them involved in a different experience from the traditional authority evaluation.

Students' generic quizzes: Analysis and samples

Out of twenty, thirteen students handed in their assignments. Ten of the submitted quizzes were in a standard format. Each question was on a separate A4 page along with its solution. Papers were filed with a cover page and with questions and solutions

neatly written out. Four students used a computer to print out their questions and part of their answers (graphs).

Browsing through the quizzes, it was evident that most students were very much affected by the homework assignments they were given. Most of their questions reflected, in one way or another, questions given or seen previously. Most of the students tried to at least change, somehow, the data given. As an example of this behaviour see Figure 3.

(A) Draw the graph of the line $-2x + y = 4$.

(B) Given $\ell : 5x + 15y = 30$. (a) Find the gradient of ℓ. (b) Find the intercepts of ℓ. (c) Draw the graph of ℓ.

Figure 3: (A) Previously-seen problem. (B) Problem in a generic quiz produced by a student.

Of course this was to be expected as our course, Basic Mathematics 1, is a fundamental level course where content objectives are few. Comparing questions in student generic quizzes to previously seen or assigned questions, from Figure 3 it is evident that the student had moved the question to a higher cognition level (Bloom, 1956). Here the student had analysed the steps required to graph the equation and broke it down into different parts. Clearly, for a student to make up such a problem he/she must have comprehended the strategy required to draw the graph of a given line and was thus able to recall knowledge and reformulate steps used in previous questions. On the other hand, some students elaborated on previously-seen questions and it was clear that they had a deeper understanding of the content (see Figure 4). In this question the student communicated a difference between knowledge types in order to make up the question. He/she connected the concept of the gradient of a line to the concept of perpendicular lines. This shows a more complicated thinking process to construct such a problem compared to the one given in Figure 2.

Overall, students participating in this experiment were more confident and relaxed during the regular in-class quizzes compared to those who did not. Most of the usual questions from students during the quiz, such as 'Teacher, do you mean we need to find the equation of the line in this question?', 'Teacher, you did not give us a similar question?' were raised by those who had not bothered to play the generic quiz game.

Students' feedback

All students who participated in the generic quiz, except one, reflected positively on the experience. They agreed that the generic quiz deepened their understanding and made them connect different ideas covered in the material. Students who actively participated

(A) A line ℓ passes through the point $(2, 5)$ and $(6, Y)$. If the line has a gradient of -3, find the value of Y.

(B) A line ℓ_1 passes through the point $(-1, -4)$ and $(4, Y)$. ℓ_1 is perpendicular to the line ℓ_2. If line ℓ_2 has a gradient of 2/3, find the value of Y.

Figure 4: (A) Previously-seen problem. (B) Problem in a generic quiz produced by a student.

in this activity asked for more. The difficulty they said they experienced was in trying to come up with questions which were not similar to previously-asked questions. This made them connect the different parts of the material covered, which required them to know the details of every section. One student commented:

> I have never had a tool to revise before a quiz better than this way. It made me jump from one idea to another to make the best question I could.

Summary and recommendations

If we are to prepare our students to solve problems, then they should be able to define the problem and devise strategies to solve it. This implies that students should know how to find out information, how to present it, and how to use it to solve a problem. As such, the generic quiz presented above proves to be an efficient tool in motivating students to construct information and to define a problem along with a strategy as to how to solve it. Activities similar to the generic quiz are excellent opportunities for students to practise different thinking and learning skills to improve their abilities when it comes to real-life problems. The generic quiz also forms a solid basis for students who go on to work on either open-ended or project type problems.

References

ARNOLD, J.E. (1962). *Useful Creative Technique: A source book for creative thinking* Scribners.

BARRON, F. AND HARRINGTON, D. M. (1981). Creativity, Intelligence and Personality, *Annual Review of Psychology*, **21**, 439.

BLOOM, B. S. (Ed.) (1956). *Taxonomy of educational objectives – Handbook I: Cognitive Domain*. Harper and Row: New York.

DE BONO, E. (1970). *Lateral Thinking*. Harper and Row: New York.

FELDER, R. M. (1985). The generic quiz: A device to stimulate creativity and higher level thinking skills, *Chemical Engineering Education*, 176.

FELDER, R. M. (1987). On creating creative engineers, *Engineering Education*, **78**, 222, and references therein.

WOODS, D.R. (1983). Ideas on encouraging academic excellence, *Engineering Education*, **74**(2), 99.